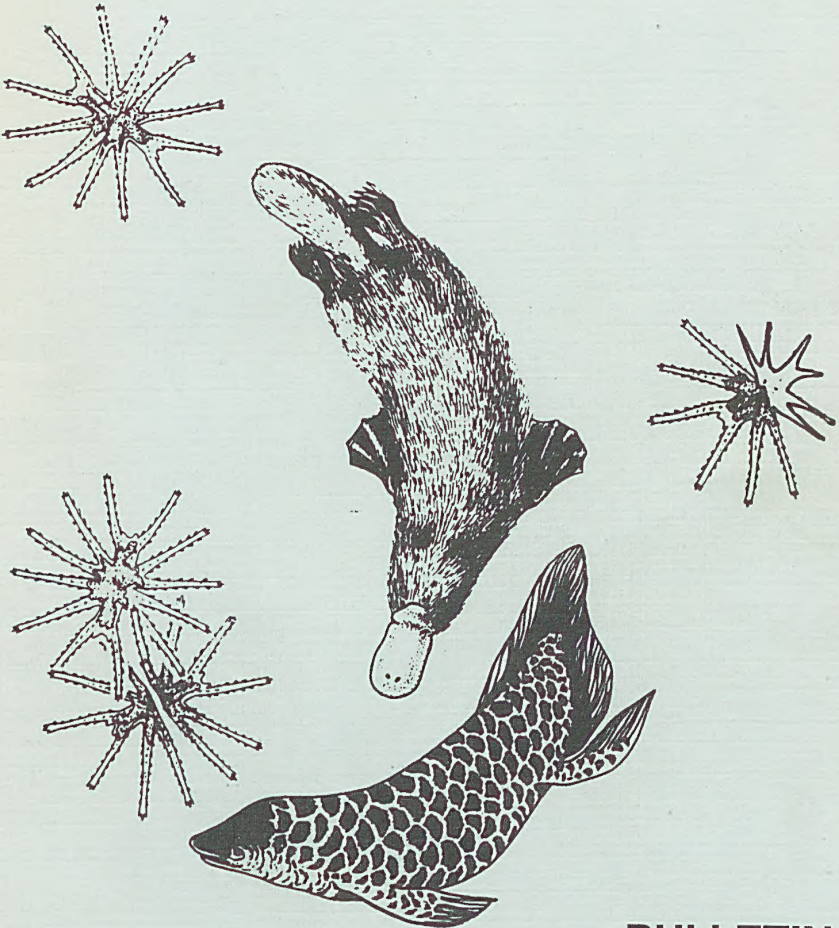


Australian Society for Limnology



BULLETIN
No. 11

NOTES TO AUTHORS

The *Bulletin* will accept for publication *original contributions*, subject to the following conditions:

1. Papers not directly related to Australia, New Zealand and New Guinea may not be accepted.
2. Taxonomic papers which describe new species will not be accepted unless any "type" material has been deposited at an Australian museum and evidence is presented of its Registration.
3. Manuscripts are to be typed, double-spaced and submitted in duplicate.
4. Photographs will be accepted only in exceptional circumstances.
5. Line drawings, graphs, etc., must be kept to a minimum.
6. All papers will be subject to refereeing.
7. Abbreviated titles of journals cited in "*References*" must conform with the *World List of Scientific Periodicals* abbreviations.
8. 25 reprints will be made available to the author free; additional reprints will be provided at cost.
9. Book reviews may be accepted for publication.

All communications should be addressed to Dr P.S. Lake, the Editor, Department of Zoology, Monash University, Clayton, Victoria, 3168.

AUSTRALIAN SOCIETY FOR LIMNOLOGY

BULLETIN No. 11

AUGUST, 1987

Edited by P.S. Lake and D.W. Morton.

AUSTRALIAN SOCIETY FOR LIMNOLOGY
BULLETIN No. 11

Edited by P.S. Lake and D.W. Morton

CONTENTS

	Page
B.V. TIMMS and C.H.S. WATTS Water beetles of salt lakes near Colac, Victoria	1
B.V. TIMMS Colonization of two large farm dams on the central coast of New South Wales by crustacean zooplankton	9
M.A. O'KEEFE and P.S. LAKE The decomposition of pine, eucalypt and <i>Acacia</i> litter in a small upland Victorian stream	15
M.E. McKAIGE Comparison of two net emptying frequencies in the assessment of drift sampling as a potential biological monitoring tool	33
B.C. CHESSMAN and W.D. WILLIAMS A note on the diet of <i>Galaxias maculatus</i> (Jenyns) (Pisces, Salmoniformes, Galaxiidae) in a closed saline lake in western Victoria	43
T.J. DOEG Macroinvertebrate communities in the Goulburn River and tributaries above Lake Eildon, Victoria	47

WATER BEETLES OF SALT LAKES NEAR COLAC, VICTORIA

by

B.V. Timms¹ and C.H.S. Watts²

1. Sciences Department, Avondale C.A.E., Cooranbong, N.S.W. 2265.
2. Evolutionary Biology Unit, South Australian Museum, North Terrace, Adelaide, 5000.

Abstract

Nineteen species of water beetles were caught in 24 saline lakes near Colac, with *Megaporus howitti*, *Necterosoma penicillatum* and *Enochrus* nr *andersoni* the most widespread. Few species apparently breed in the lakes. There was only a loose inverse relationship between salinity and species richness partly because of habitat differences between lakes. Species richness and salinity ranges are about the same as for water beetles in North American saline lakes, but Australian species are endemic and the genera different.

Introduction

Since the pioneering study by Bayly and Williams (1966) on some saline lakes in southeast Australia, there has been a number of surveys and ecological studies on the fauna of Australian salt lakes (see reviews by Williams, 1978, 1981). As a result, many ecological data are available for some taxa, especially crustaceans, but for others information is still scant. One such group is the aquatic Coleoptera. Studies to date list only 10 species — the dytiscids *Bidessodes* sp., *Megaporus howitti* (Clark), *Lancetes lanceolatus* Clark, *Necterosoma penicillatum* Clark and *Rhantus suturalis* (MacLeay), the hydrophilids *Berosus australiae* Muls, *Enochrus* nr *andersoni* (Blackburn), *Hydrobius assimilis* Hope, *Hydrophilus latipalpus* Castelnau and the curculionid *Bagous* sp. (Bayly and Williams, 1966; Halse, 1981; Lim, 1964; Pollard, 1971; Timms, 1973; Walker, 1973), yet reconnaissance of some lakes at Red Rock, near Colac, suggests a much richer fauna. It is the aim of this work to document the diversity and salinity range of beetles in saline lakes near Colac.

Methods

Twenty four lakes covering a salinity range of 1.3-203 g l⁻¹ were selected for study in the Colac-Camperdown-Lismore area of the Western District of Victoria (Table 1). Two person-hours were spent in each searching for water beetles with a pond net. In addition to salinity measurements with a conductivity meter, notes were made on the relative abundance of rocks, aquatic plants, and the roughness of inshore water (waves often hampered searching).

Table 1. The study lakes — some environmental factors and the number of beetle species in each.

Lake	Code	Rockiness†	Macrophyte† abundance	Protection†	Salinity g l ⁻¹	Number of species of beetles
Colac	C1	+++	++	++	1.3	8
Purdigulac	P	+++	++	++	1.4	4
Modewarre	M	+	++		4.0	1
Coragulac*	C2	+++	+++	+++	4.1	6
Loc D* <i>sensu</i>						
Bayly 1969	D	++	+	+++	6.0	11σ
Coradgill	C3	+++	+	++	7.3	5
Kariah	K	+++	+++	++	7.7	9
Colongulac	C4	+			9.7	2
Koreetung	O	++		+	10.6	1σ
Gnarput	G			+	11.0	0
Bookar	B	+	++	+	13.3	2
Red Rock Tarn*	R	++		+++	13.4	8σ
West Twin*	T	++	+	+	14.8	3
East Twin*	U	++	+	++	16.8	3σ
Werowrap*	W	+++		+	20.9	1
Gnarlinegurk*	N	+++		++	24.1	3σ
Corangamite	C5	+++			30.4	2
Barney Bolac	A	+	+	+	38.7	1
'Missen's L', via Beeac	-			+	82.4	0
Terang Goodwitch	-			++	103.9	0
Terrinallum	-	+		++	118.8	0
Pink	-			+	142.8	0
Tatutong	-	+		++	203.9	0

† Determined subjectively on a scale of zero to +++. These designations apply only to conditions at the time and place of collection.

σ Larvae present (data from Timms, 1983).

* One of the Red Rock lakes.

In collecting beetles from these lakes a major problem arose in knowing when all the species living in a lake at that time were collected; beetles were often few in number or unevenly distributed or both. Field experience suggested that almost all of the species caught in a lake were obtained within the first hour of collecting, but occasionally extra species were caught after 1½ hours or even 2 hours. A two-hour time limit was found to be a practical compromise.

The beetles were identified by C.H.S.W. and voucher specimens are now stored in the ecology reference collection at Avondale College.

Results

Nineteen species were collected from the saline lakes (ie. salinity >3 g l⁻¹) in the series; another was encountered only at 1.3 g l⁻¹ (Figure 1). Three families were represented, with the most common species being the dytiscids *Megaporus howitti* and *Necterosoma penicillatum* and the hydrophilid *Enochrus* nr *andersoni*. Seven species could be regarded as

being uncommon in the lakes studied, there being just one record of each (Figure 1).

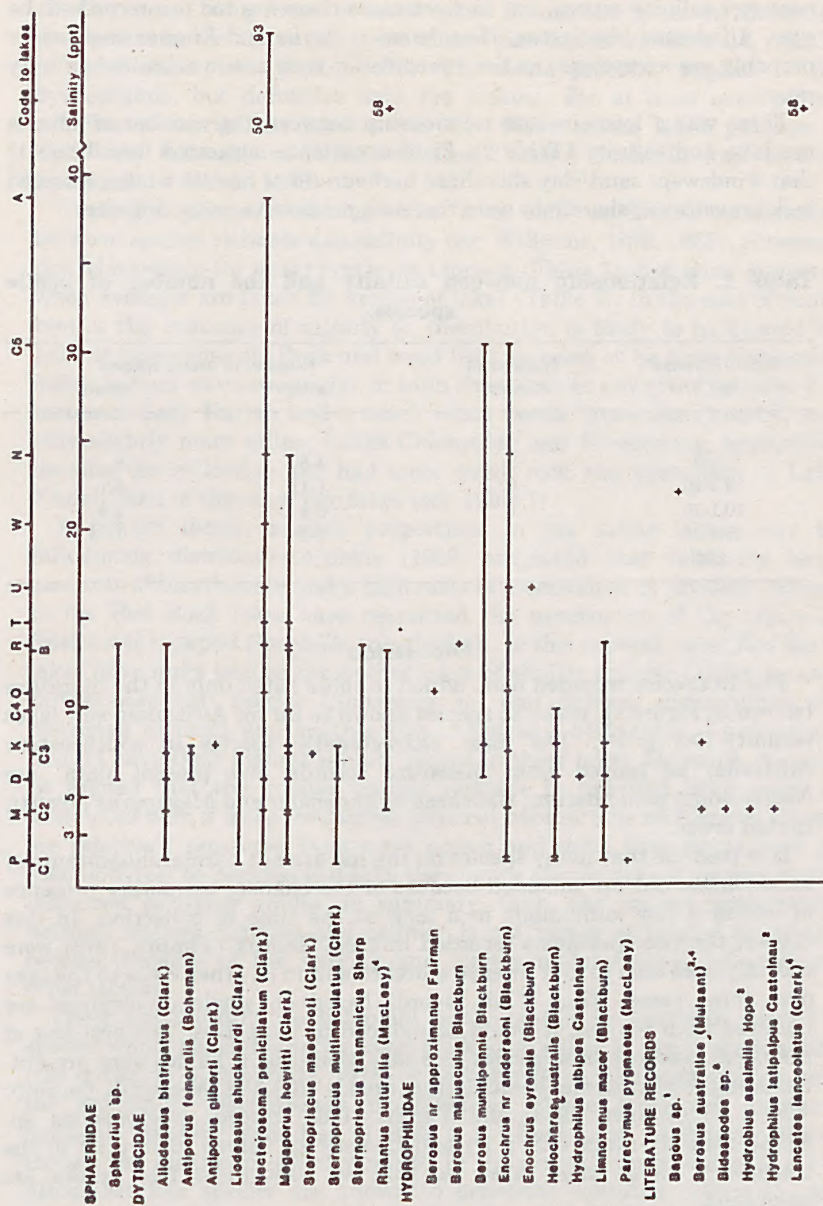


Fig. 1 Distribution of the coleopteran species in the salt lakes. Abbreviations from the lakes are as in Table 1. ¹ from Bayly and Williams, 1966; ² from Lim 1964; ³ from Pollard 1971; ⁴ from Timms 1973].

Necterosoma penicillatum had the widest salinity range, 1.3-38.7 g l⁻¹. *Berosus munitipennis*, *Enochrus* nr *andersoni* and *Megaporus howitti* also had wide salinity ranges. The remaining species probably had much narrower salinity ranges, but in most cases there are too few records to be sure. *Alloedessus bistrigatus*, *Helochaeres australis* and *Limnoxenus macer* probably are exceptions, as the 5 records for each are in a limited salinity range.

There was a loose inverse relationship between the number of species per lake and salinity (Table 2). Field experience suggested (see Table 1) that windswept sand/clay shorelines harboured few beetles while protected rock/gravel/weed shorelines were the most productive collecting sites.

Table 2. Relationship between salinity and the number of beetle species.

Salinity range (g l ⁻¹)	Number of lakes	Number of beetle species range	mean
1-3	2	4-8	6
3.1-10	6	1-11	5.7
10.1-20	6	0-8	2.8
20.1-40	4	1-3	1.75
>40	5	0	0

Discussion

The 19 species recorded here, added to those listed only in the literature (shown in Figure 1), make 25 species known so far for Australian salt lakes (salinity >3 g l⁻¹). The most characteristic species in southeastern Australia, as judged from literature records and present data, are *Necterosoma penicillatum*, *Enochrus* nr *andersoni* and *Megaporus howitti*, in that order.

It is possible that many species on the list are not normal inhabitants of saline lakes, but are included because of the chance, temporary presence of one or a few individuals in a lake at the time of collection. In this respect the two specimens recorded in Lake Gnotuk (Timms, 1973) were the only ones seen in four intense searches and in 32 other visits to the lake over three years. Thus if all records based on single occurrences are removed from the list, it would be reduced to 14 species. The best test of the usual presence of a species in a lake would be if larvae were present. Certainly *Necterosoma penicillatum* breeds in Lake Werowrap (salinity <20 g l⁻¹) (Walker, 1973) and Timms (1983) records *Necterosoma* sp. larvae (salinity range 6-24 g l⁻¹) and *Berosus* sp. larvae (6-15 g l⁻¹) in the benthos of these same lakes, so that at least these two genera are halophilic.

The 25 species recorded thus far from Australian salt lakes belong to four families — the Dytiscidae and Hydrophilidae are of similar

importance with 12 and 11 species respectively and the Sphaeriidae and Curculionidae are each represented by one uncommon species. There are no indications of the other common and widespread water beetle family, the Gyrinidae, being found in saline lakes. Among the dytiscids, almost all the species in the saline lakes are widely distributed in Australia, usually in fresh water (see Watts, 1978). The same probably applies to the hydrophilids, but definitive data are lacking. For at least one species, *Allodessus bistrigatus*, presence in the Colac saline lakes provides a significant extension of its known range ('inland Australia' and 'rare on east coast' — Watts, 1978).

Typically, groups inhabiting saline lakes show an inverse relationship between species richness and salinity (eg. Williams, 1978, 1981). However, the relationship for water beetles is tenuous (Table 1), but more apparent when averages are taken for groups of lakes (Table 2). In the case of water beetles the influence of salinity on distribution is likely to be blurred by habitat requirements. Rock and weed littorals seem to be more favourable habitats than wave-swept clay or sand shorelines at any given salinity. For instance, Lake Kariah had a much richer beetle fauna than nearby, and only slightly more saline, Lakes Colongulac and Koreetnung, apparently because the collecting site had more weed, rock and protection in Lake Kariah than in the other two lakes (see Table 1).

A further factor, anionic proportions in the saline lakes, may be influencing distribution. Bayly (1969) suggested that relatively large amounts of bicarbonate and a high ratio of monovalent to divalent cations in the Red Rock lakes have permitted the penetration of the typically freshwater copepod *Boeckella triarticulata*. In this context, most Red Rock lakes have more beetles than other lakes of similar salinity (Table 1), and furthermore two beetles (*Sphaerius* sp. and *Berosus majusculus*) are restricted to them and another two (*Allodessus bistrigatus*, *Limnoxenus macer*) have their highest salinity record in these lakes. However, it could be argued that the greater species richness in the Red Rock lakes is associated with a more favourable physical habitat (the rock/gravel shores are relatively protected from wave action and some have dense beds of macrophytes) or perhaps is due to the chance distribution of species easily dispersed as flying adults. In summary, then, the inverse relationship between species richness and salinity is not highly correlated for water beetles, because of the varying and largely undetermined influence of other factors.

There are probably no halobiont water beetles in Australia since all species which penetrate saline lakes are known either to live in fresh water (the dytiscids — see Watts, 1978) or probably do so (the hydrophilids and the sphaerid). *Necterosoma penicillatum* is the most salt tolerant halophil, reaching salinities of 92.6 g l⁻¹ (Bayly and Williams, 1966), though the maximum salinity record in the present study was 38.7 g l⁻¹. Altogether five species are known to penetrate salinities >30 g l⁻¹, six species >20 g l⁻¹, 13 species >10 g l⁻¹ and 25 species >3 g l⁻¹ (see Figure 1).

Though insects, including water beetles, are relatively unimportant in Australian saline lakes *vis-a-vis* saline lakes overseas (eg. Geddes *et al.*, 1981), there seems to be little difference in the number of species of water beetle involved or in the upper limits reached. Although Rawson and Moore (1944) report 37 species in their study of Saskatchewan saline lakes, most of these were restricted to waters not considered saline here (ie. salinities $<3 \text{ g l}^{-1}$) and only one species penetrated the salinity gradient to any degree (to 118 g l^{-1}). Scudder (1969) lists two species in highly saline waters of British Columbia and a further three in lakes of lower salinity. Lauer (1963) mentions only one halophilic beetle in his work on two saline lakes in Washington, and Galat *et al.* (1981) list 6 species for Pyramid Lake, Nevada (salinity 5.3 g l^{-1}).

Almost all macroinvertebrates in Australian salt lakes are endemic at the rank of species, genus and often family (Bayly and Williams, 1973; Williams, 1981; Geddes *et al.*, 1981) and the same largely applies to the water beetles. Australian halophilic species are endemic, most of the genera involved are different from those known in saline lakes overseas (though they may occur in freshwaters there, eg. most hydrophilid genera), but the families involved are largely similar. The difference at the family level is the penetration of the Sphaeriidae into saline waters in Australia, while at the generic level *Enochrus* and *Rhantus* live in salt lakes in both North America (Galat *et al.*, 1981; Rawson and Moore, 1944; Scudder, 1969) and Australia.

Acknowledgements

We wish to thank Sue Boyer, Laurene Orel and Owen Robinson for field assistance and Dr. K.E. Walker of Adelaide University for comments on the manuscript.

References

- Bayly, I.A.E. (1969). The occurrence of calanoid copepods in athalassic saline waters in relation to salinity and ionic proportions. *Verh. Int. Verein. Limnol.* 17: 449-455.
- Bayly, I.A.E. and Williams, W.D. (1966). Chemical and biological studies on some saline lakes of south-east Australia. *Aust. J. Mar. Freshw. Res.* 17: 177-228.
- Bayly, I.A.E. and Williams, W.D. (1973). 'Inland Waters and their Ecology.' (Longman, Melbourne).
- Geddes, M.C., De Deckker, P., Williams W.D., Morton, D.W. and Topping, M. (1981). On the chemistry and biota of some saline lakes in Western Australia. *Hydrobiologia*. 81/82: 201-222.
- Galat, D.L., Lider, E.L., Vigg, S. and Robertson, S.R. (1981). Limnology of a large, deep, North American terminal lake, Pyramid Lake, Nevada, USA. *Hydrobiologia*. 81/82: 281-317.
- Halse, S.A. (1981). Faunal assemblages of some saline lakes near Marchagee, Western Australia. *Aust. J. Mar. Freshw. Res.* 32: 133-142.

- Lauer, G.J.** (1963). The bottom fauna of two saline lakes in the Grand Coulee, Washington. Ph.D. Thesis, University of Washington.
- Lim, K.H.** (1966). The biology of *Austrochiltonia subtenuis* (Sayce, 1902). M.Sc. Thesis, Monash University.
- Pollard, D.A.** (1971). Faunistic and environmental studies on Lake Modewarre, a slightly saline athalassic lake in southwest Victoria. *Bull. Aust. Soc. Limnol.* 4: 25-42.
- Rawson, D.S. and Moore, J.E.** (1944). The saline lakes of Saskatchewan. *Can. J. Res., Ser D.* 22: 141-201.
- Scudder, G.G.** (1969). The fauna of saline lakes on the Fraser Plateau in British Columbia. *Verh. Int. Verein. Limnol.* 17: 430-439.
- Timms, B.V.** (1973). A comparative study of the limnology of three maars in western Victoria. Ph.D. Thesis, Monash University.
- Timms, B.V.** (1983). A study of the benthic communities of some shallow saline lakes of western Victoria, Australia. *Hydrobiologia.* 105: 165-177.
- Walker, K.F.** (1973). Studies on a saline lake ecosystem. *Aust. J. Mar. Freshw. Res.* 24: 21-71.
- Watts, C.H.S.** (1978). A revision of the Australian Dytiscidae (Coleoptera). *Aust. J. Zool. Suppl. Ser.* No. 57: 1-166.
- Williams, W.D.** (1978). Limnology of Victorian salt lakes. *Verh. Int. Verein. Limnol.* 20: 1165-1174.
- Williams, W.D.** (1981). The limnology of saline lakes in western Victoria. *Hydrobiologia.* 81/82: 233-259.

COLONIZATION OF TWO LARGE FARM DAMS ON THE CENTRAL COAST OF NEW SOUTH WALES BY CRUSTACEAN ZOOPLANKTON

by B.V. Timms

Sciences Department, Avondale C.A.E., Cooranbong, N.S.W. 2265.

Abstract

Plankton assemblages, typical for the region, were soon acquired by the accrual of species according to their previously ascertained dispersal abilities. A shift in dominance from *Boeckella minuta* to *Calamoecia lucasi* occurred after the first 1-2 years suggesting that the former is a fugitive species often competitively disadvantaged by the latter.

Introduction

Twenty years ago, Bayly (1966) lamented that a 'procession of successions' were going unstudied in the new water storages being built all over the country. His admonition for studies of ecological succession in them has gone largely unheeded, despite the greater number of limnologists in Australia now, and an even greater obsession by governments and landowners to build new dams.

Perhaps the easiest community to study in a waterbody for early succession patterns is the zooplankton. Two studies (Jolly (1966) on Lakes Burragorang and King (1979) on North Pine Reservoir) detected no significant successional changes in species composition over the study period (6 years and 32 months respectively), but both studies commenced some time (*ca* 3 years and 7 months respectively), after impoundment. Changes in composition could occur in the first few months, reflecting different dispersal abilities (Maly, 1984a; Timms, 1970a); on the other hand ecosystem maturation could again shift community structure (Brooks, 1969). Hence, long term studies commencing with impoundment are desirable. This paper reports on the first phase of such a study on two large farm dams on the Central Coast of New South Wales.

Sites and Methods

Morisset Golf Club Dam lies 2 km southwest of Morisset, has a volume of 44 MI, surface area of 3 ha and maximum depth of 3.2 m. It was built in early 1975 by excavation and damming of a small valley; it commenced filling in February 1975. Moncrief's Dam is situated 3.5 km north of Cooranbong and was built in late 1978 with little disturbance of the basin. It has a volume of 62 MI, a surface area of 5 ha, a maximum depth of 2.5 m, and commenced filling in March 1979. Each dam was visited at 2-monthly intervals from soon after impoundment (2 month delay for Morisset, 4 month delay for Moncrief's) till December 1979 for Morisset

and December 1980 for Moncrief's, with the exception of July 1978 to June 1979 when no collections were made. During 1980 and 1981 Morisset Dam was visited at monthly intervals, except for July 1981. The same program operated in Moncrief's Dam during 1981.

On each visit a plankton net of 33 cm aperture and mesh size 159 μ m was towed obliquely from 2-0.25 m depth over a marked distance in a set time, so that approximately 4 m³ of water were filtered. The net was thoroughly washed after each haul to prevent future contamination. Plankton was preserved in 8% formalin, and subsampled for enumeration. Cladocerans and calanoid copepods were identified to species, but for the cyclopoid copepods this was achieved on only a few individuals in about half the collections.

Results

In the Morisset Dam (Figure 1), the earliest colonizers were *Boeckella minuta* and cyclopoids (*Mesocyclops albicans*, *Microcyclops varicans*) followed in order by *Moina micrura*, *Bosmina meridionalis*, *Boeckella fluvialis*, *Ceriodaphnia cornuta*, *Calamoecia lucasi*, *Thermocyclops crassus*, *Daphnia carinata* and finally *Ceriodaphnia* sp. The initial plankton community was dominated by *Boeckella minuta* and cyclopoids (mainly *Microcyclops varicans*) with *Moina micrura* and

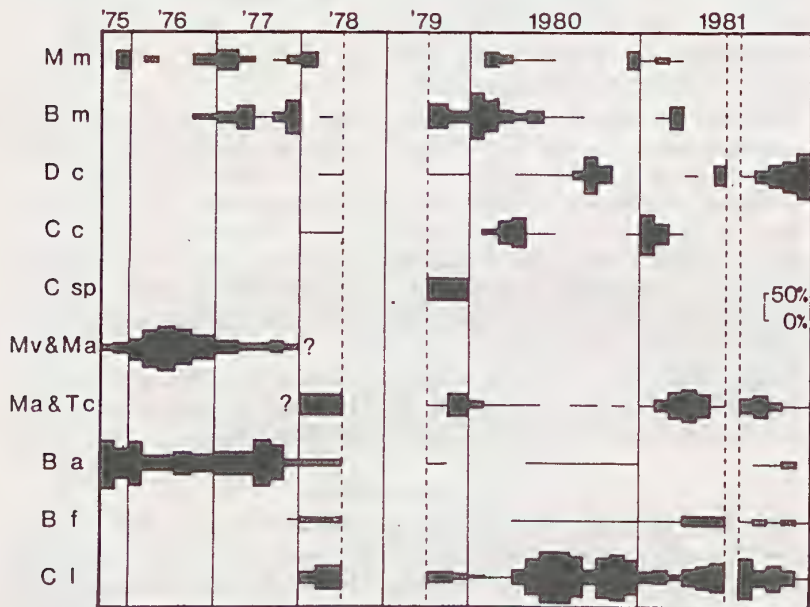


Fig. 1 Succession of crustacean zooplankton in Morisset Golf Club Dam 1975-1981. Spaces between dashed vertical lines indicate no data. Abundances expressed as percentage composition. Code to species: Mm = *Moina micrura*, Bm = *Bosmina meridionalis*, Dc = *Daphnia carinata*, Cc = *Ceriodaphnia cornuta*, C.sp. = *Ceriodaphnia* sp., Mv = *Microcyclops varicans*, Ma = *Mesocyclops albicans*, Tc = *Thermocyclops crassus*, Ba = *Boeckella minuta*, Bf = *Boeckella fluvialis* and Cl = *Calamoecia lucasi*.

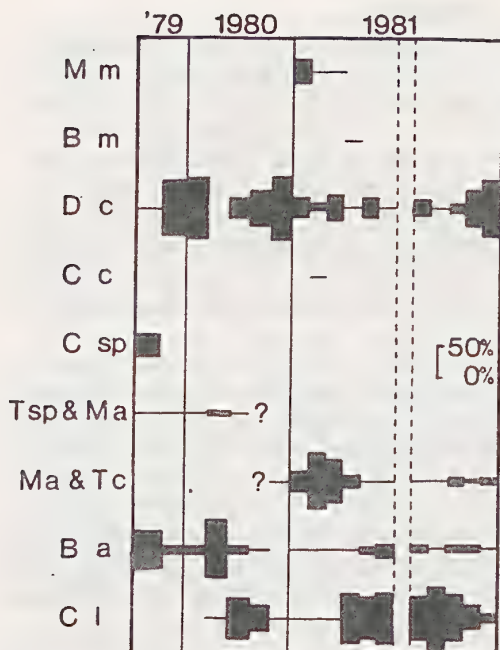


Fig. 2 Succession of crustacean zooplankton in Moncreif's Dam 1979-1981. Other information as in Fig. 1 plus T sp = *Tropocyclops* sp.

Bosmina meridionalis according to season. By 1980-81 there had been a shift to dominance by *Calamoecia lucasi*, cyclopoids (mainly *Thermocyclops crassus*) and *Daphnia carinata*, with *Ceriodaphnia cornuta*, *Moina micrura*, and *Bosmina meridionalis* according to season. *Boeckella minuta* was still present occasionally, but *Ceriodaphnia* sp. was not seen during 1980-81.

Events in Moncreif's Dam (Figure 2) were somewhat different with *Boeckella minuta*, *Ceriodaphnia* (?) *quadrangula*, *Mesocyclops albicans*, *Tropocyclops* sp. and *Daphnia carinata* the colonizers and *Calamoecia lucasi*, *Moina micrura*, *Ceriodaphnia cornuta*, *Bosmina meridionalis* and *Thermocyclops crassus* added later. The early community was dominated by *Boeckella minuta* and *Daphnia carinata* and the latter by *Calamoecia lucasi* and *Daphnia carinata*.

The 3 calanoid copepods were perennially present while the 4 cyclopoid copepods were almost perennial. The 5 cladocerans were distinctly seasonal, excepting *Daphnia carinata* in Moncreif's Dam where it was present on almost all occasions. *Moina micrura*, *Bosmina meridionalis* and *Ceriodaphnia cornuta* were most abundant in summer and autumn, *Daphnia carinata* typically bloomed in spring/early summer, while no seasonality could be detected for *Ceriodaphnia* sp.

Discussion

Both study dams soon gained zooplankton communities characteristic of the region, i.e. a community of ca 8-10 crustaceans usually including *Boeckella fluvialis*/*B. minuta*/*Calamoecia lucasi*, various cyclopoids (often *Mesocyclops albicans*, *Thermocyclops decipiens*), *Daphnia carinata*/*D. lumholtzi*, *Ceriodaphnia cornuta*, *Moina micrura*, *Bosmina meridionalis* and *Diaphanosoma excisum* (Timms, 1970a, 1970b). The most significant differences are in the lack of *D. excisum* and *D. lumholtzi* and in the punctuated presence of *Ceriodaphnia* sp. The latter species occurs in some years in lagoons associated with the lower Hunter River (author, unpublished data) while at least *D. excisum* seems to be restricted to natural lagoons in the area.

While differences between the two dams could be due to chance it is possible that their different environments contribute. Waters of Morisset Dam were turbid, generally alkaline (mean pH 7.6) and had an early population explosion of *Gambusia affinis*, while Moncrief's Dam contained clearer, slightly humic water (mean pH 6.8) in which fish, except eels, were absent. It is thought that the absence of planktivorous fish (eg. Brooks and Dodson, 1964) and perhaps slightly humic water made Moncrief's Dam more favourable for *Daphnia carinata*, and that the latter factor made it less favourable for other cladocerans (eg. Timms, 1969) and perhaps also for *B. fluvialis*.

The order of arrival of the various species concurs largely with the known relative dispersal powers of entomostracans in Australia. *Boeckella* generally arrives before *Calamoecia* because of the larger clutches it produces (Maly, 1984a). In northeastern New South Wales *Boeckella minuta*, some cyclopoids (particularly *Mesocyclops albicans*) and *Daphnia carinata* disperse easily (Timms 1970a). *Thermocyclops crassus*, *Ceriodaphnia cornuta*, and in these cases *B. fluvialis*, are later immigrants while *Daphnia lumholtzi* and *Diaphanosoma excisum* are sluggish dispersants and have yet to arrive in these dams. The time interval between arrivals of each species is variable and, among other factors, could be determined by their relative abundance in the area. As an example, *C. lucasi*, which is widespread in northeastern New South Wales but relatively uncommon in southern Victoria, took less than three years to colonize these dams but ca. 10 years to arrive in the Jock Marshall Reserve Pond in Melbourne (I.A.E. Bayly, personal communication). The early arrival of *B. minuta* and its subsequent decline in importance is in accord with Bayly's (1978) claim that this species is a sluggish fugitive (*sensu* Hutchinson, 1951). Its marked sexual dimorphism, unusual in species inhabiting permanent waters (Bayly, 1978) confers a feeding advantage and its small males are able to utilize food too small for its congeners. Hence it can build large populations quickly if given the opportunity. However, when *C. lucasi* arrives its females, which are of similar size to males of *B. minuta* (Bayly, 1978), may compete with them for food (Hutchinson, 1951). Certainly intrageneric matings for this pair are impossible (Maly, 1984b), so that changes in their relative abundance

cannot be explained by Maly's interspecific copulation theory. In any case, in these dams *C. lucasi* replaces *B. minuta* as the dominant calanoid. It is also the dominant calanoid in most older reservoirs and lakes in the area (Timms, 1970a, 1970b, unpublished data) while in new reservoirs *B. minuta* is typically present alone.

In conclusion, rapid changes occurred in the first year or two in the zooplankton of these small reservoirs, mainly by the accrual of species but also by the shift in dominance. By contrast, both Jolly (1966) and King (1979) did not record any changes. It is possible that they missed them because of delay in the commencement of their studies after impoundment; furthermore, colonization may be quicker in large reservoirs because the large surface area increases the chances of successful arrival by dispersants. All of the studies on reservoirs of various ages in New South Wales and southeast Queensland (Jolly, 1966; Timms, 1968, 1970a Appendix, 1970b) suggest that the zooplankton assemblages gained after a year or two are likely to be stable, except for seasonal changes, for decades. In the longer term there may be a move to a simpler community as 3 local small reservoirs (40—ca 70 years old) contain acid (pH 6.0-6.5) water and a zooplankton dominated by *Boeckella minuta* and *Mesocyclops albicans* (Timms 1970a Appendix). It will be interesting to see if this eventuates in Morisset Golf Club Dam and Moncrief's Dam, or whether the heavy fertilization of the catchments with fowl manure and/or fallout from the local power stations will cause changes not envisaged.

Acknowledgements

I wish to thank the Morisset Golf Club and the Moncrief family for access to their properties, the students of Ecology II classes 1975-1981 for field assistances, Prof. C.H. Fernando for identification of cyclopoids and Dr. I.A.E. Bayly for his comments on the manuscript.

References

- Bayly, I.A.E. (1966). Our procession of successions. *Aust. Soc. Limnol. Newslt.* 5 (2): 26-27.
- Bayly, I.A.E. (1978). Variation in sexual dimorphism in nonmarine calanoid copepods and its ecological significance. *Limnol. Oceanogr.* 23: 1224-1228.
- Bayly, I.A.E. and Williams, W.D. (1973). 'Inland Waters and their Ecology.' (Longmans, Melbourne).
- Brooks, J.L. (1969). Eutrophication and changes in the composition of the zooplankton. In: 'Eutrophication: Causes, Consequences, Correctives.' (National Academy of Sciences, Washington), pp.263-255.
- Brooks, J.L. and Dodson, S.L. (1965). Predation, body size, and composition of plankton. *Science* 150: 28-35.
- Hutchinson, G.E. (1951). Copepodology for the ornithologist. *Ecology* 32: 571-577.

- King, C.R.** (1979). Secondary productivity of the North Pine Dam. *Aust. Water Res. Council, Tech. Pap. No. 39*.
- Jolly, V.H.** (1966). The limnetic Crustacea of six reservoirs in the Sydney area of New South Wales. *Verh. Int. Verein Limnol.* **16**: 727-734.
- Maly, E.J.** (1984a). Dispersal ability and relative abundance of *Boeckella* and *Calamoecia* (Copepoda: Calanoida) in Australian and New Zealand waters. *Oecologia* **62**: 173-181.
- Maly, E.J.** (1984b). Interspecific copulation in and co-occurrence of similar-sized freshwater centropagid copepods. *Aust. J. Mar. Freshw. Res.* **35**: 153-165.
- Timms, B.V.** (1968). Comparative species composition of limnetic planktonic crustacean communities in south-east Queensland. *Hydrobiologia* **31**: 474-480.
- Timms, B.V.** (1969). A limnological survey of the Woolli Lakes, New South Wales. *Proc. Linn. Soc. N.S.W.* **94**: 105-112.
- Timms, B.V.** (1970a). Chemical and zooplankton studies of lentic habitats in north-eastern New South Wales. *Aust. J. Mar. Freshw. Res.* **21**: 11-33.
- Timms, B.V.** (1970b). Aspects of the limnology of five small reservoirs in New South Wales. *Proc. Linn. Soc. N.S.W.* **95**: 46-59.

THE DECOMPOSITION OF PINE, EUCALYPT AND ACACIA LITTER IN A SMALL UPLAND VICTORIAN STREAM

by

M.A. O'Keefe and P.S. Lake

Department of Zoology, Monash University, Clayton, Victoria 3168

Abstract

The decomposition of leaves of *Eucalyptus viminalis*, needles of *Pinus radiata* and phyllodes of *Acacia melanoxylon* was examined at two sites on a small first-order upland stream in southern Victoria. One of the sites was located in a pine plantation while the other was in native eucalypt forest. The decomposition rates of pine and eucalypt litter were rapid, placing them in the fast processing category of Petersen and Cummins (1974), but *Acacia* litter decomposed slowly. Protein concentrations of all three litter types increased with decomposition. The macroinvertebrate fauna collected from the litter bags was dominated by shredders. Shredders were more abundant in the litter bags at the eucalypt site than at the pine site. The invertebrate densities peaked on the pine and eucalypt litter in the first two to three weeks, and the numbers of invertebrate taxa on all three litter types also peaked relatively early during the decomposition phase. Results on the decomposition of eucalypt and pine leaf litter in freshwater ecosystems are summarized.

Introduction

In common with similar small northern hemisphere streams with forested catchments, small streams in temperate Australia are assumed to be heterotrophic (Blackburn and Petr, 1979). The native forests which surround streams in temperate Australia are evergreen and are usually dominated by eucalypt trees. Some observers of Australian upland streams have therefore regarded the litter input into such streams as being continuous and constant (e.g. Williams and Wan, 1972; Hynes and Hynes, 1975). However, observations of litter fall from Australian sclerophyll forests have revealed that while the litter fall is continuous it is also markedly seasonal, with the period of maximum leaf fall occurring in summer (Lake, 1982). Thus streams in temperate Australia receive the major part of their leaf input in summer when water temperatures may be high and discharge low — a timing of leaf input which is in sharp contrast to that of Northern Hemisphere deciduous forest streams. Alongside many upland streams in south-eastern Australia, two non-eucalypt evergreen trees may also be present — *Acacia melanoxylon* (Blackwood) and *Nothofagus cunninghamii* (Southern Beech). The decomposition of leaves of the New Zealand *Nothofagus solandri* has been studied by Davis and Winterbourn (1977), while Blackburn and Petr (1979) studied the decomposition of *Nothofagus cunninghamii* leaves in a small stream in

southern Victoria. In those streams where *Acacia melanoxylon* grows alongside, the leaves, or more precisely the phyllodes, of the *Acacia* may constitute a significant part of the litter entering the stream.

In south-eastern Australia, considerable areas of eucalypt sclerophyll forest have been converted to pine plantations, predominantly of *Pinus radiata* (Monterey Pine). The litter fall in such forests bears some resemblance to that of eucalypt forest in that it is continuous and has a relatively high proportion of bark, branches and fruit (Blackburn and Petr, 1979; Anderson and Sedell, 1979). However, the maximum litter fall occurs in autumn and early winter (Spain, 1973).

The decomposition of conifer needles in Northern Hemisphere streams has been examined in a number of studies (e.g. Sedell *et al.*, 1975; Triska *et al.*, 1975; Triska and Sedell, 1976; Triska and Buckley, 1978; Bärlocher *et al.*, 1978; Short *et al.*, 1980; Rosset *et al.*, 1982), although only two of these studies have considered the decomposition of *Pinus* needles (Bärlocher *et al.*, 1978; Short *et al.*, 1980). No studies have been done on the decomposition of *Pinus radiata* needles in streams or on the decomposition of any species of conifer needles in Australian streams.

The riparian vegetation of many low order streams in south-eastern Australia may now contribute very significant litter inputs from *E. viminalis*, *A. melanoxylon* and *P. radiata* to these streams. The principal aim of this study, therefore, was to observe in a small Victorian stream the decomposition of, and colonization by macroinvertebrates of, leaf litter from these three species of tree.

Description of Study Sites

The study sites were located on an unnamed first-order stream approximately 100 km north-east of Melbourne. The source of the stream (37°19'35"S, 148°28'50"E) is in the Blue Ranges (elevation 1200 metres). The stream flows into the Little River at Taggerty (37°19'27"S, 145°42'4"E). The upper part of the creek's catchment is dominated by a forest of *Eucalyptus viminalis* while the lower part has either been cleared for grazing or converted into pine plantation. The plantation around the creek is part of a 500 ha plantation of *Pinus radiata* established in 1964.

Two sites were chosen for the study. Site 1 was located 2 km from the source of the creek at an elevation of 650 m. The surrounding vegetation consisted of wet sclerophyll forest dominated by *Eucalyptus viminalis* with some *E. obliqua* (Messmate) and *E. radiata* (Narrow-leaf Peppermint). The understorey trees and shrubs included *Acacia melanoxylon*, *Coprosma quadrifida* (Prickly Currant Bush) and *Olearia argophylla* (Muskwood). The creek at this point was approximately 3 metres wide with an average depth of 8 cm. The surface layer of the bottom consisted of pebbles (Phi scale = -5, -4), cobbles (-6, -7) and some small boulders (-8).

Site 2 was located in the *Pinus radiata* plantation, 1 km downstream of Site 1, at an elevation of 600 m. At this site the banks were lined with

pinus and some *Acacia melanoxylon*. The stream was similar in dimension and in substratum to Site 1.

When the experiments began on April 22, 1982, the water temperatures at mid-day were 13°C at Site 1 and 12.5°C at Site 2. The lowest recorded water temperatures during the experiment occurred on 19 July, 1982: 5.4°C at Site 2 and 5.7°C at Site 1. Oxygen concentrations were always above saturation. The pH of the stream changed slightly during the course of the experiment from 7.8 in late summer to 6.3 in late winter. Conductivity was low: K_{18} varied from 26 $\mu\text{S}/\text{cm}$ in late summer to 51 $\mu\text{S}/\text{cm}$ in mid-winter.

Experimental Methods and Procedure

Recently abscised leaves of *E. viminalis*, needles of *P. radiata* and phyllodes of *A. melanoxylon* were collected from the ground around the creek in early March. To make the study comparable with those of other workers, the experimental litter was leached for seven days by placing it in aerated 15 litre plastic containers full of tap water at 18°C. The water was changed daily. The litter was then dried at 40°C for 3 days and the dry weight determined.

The leached leaf litter, after drying, was packed into litter bags, 20 × 10 cm, with a mesh size of 1 cm². This large mesh size was chosen to retain the leaves and to allow the largest common shredder, the amphipod *Pseudomoera fontana*, access to the litter. Because of the variation in size, shape and density of the litter types, the mesh bags were filled with equivalent volumes rather than equivalent weights of litter. As a result the initial dry weights varied, with the average weight of a eucalypt bag being 7 g, an *Acacia* bag 6 g, and the pine and control bags 5 g each.

Control bags were used to determine which animals colonized the bags for reasons other than the consumption of litter. These bags were filled with black plastic strips, in a manner similar to that of Pidgeon and Cairns (1981). The litter bags were individually labelled, weighed down with glass marbles and then tied to house bricks with nylon fishing line of 14 kg breaking strain.

Each study site was mapped for sections suitable for placing the house bricks. These sections had to be of sufficient width so that the flow pattern was not greatly disrupted by the placement of bricks and also had to be free of waterfalls and stretches of high water velocity. Within these sections the bricks were placed at random. Each brick held six bags of a particular litter type. During the experiment 84 bags were sampled from each study site during a 156 day period.

To check for any possible weight losses due to handling and transportation, three bags of each litter type were sampled on day 0 (April 22, 1982). The litter bags in the stream were sampled at random on day 0, 14, 27, 48, 69, 90 and 156. The bags were then sampled with a 250 mm mesh F.B.A. pond net and were placed individually in plastic screw-top jars. Three bags of each litter type, including the control, were sampled at

each site on each occasion. Each bag removed was replaced with a P.V.C.-strip-filled bag so that the flow pattern around the remaining experimental bags was not altered. The bags were returned immediately to the laboratory where the litter was examined under an 'Olympus' stereomicroscope and any animals were removed. The litter samples were then stored at -20°C for subsequent analysis.

The dry weight of the litter in each bag was determined by drying at 40°C for 3 days. The ash-free dry weight of the litter was determined by subsequent combustion of the litter sample at 550°C in a muffle furnace for 3 hours (Allen *et al.*, 1974).

For determination of the protein content of litter, subsamples of the litter which had been dried at 40°C were ground in a Wiley Mill (1 mm mesh). The ground litter was then treated with 0.1 N NaOH and 10% trichloroacetic acid (Kaushik and Hynes, 1968) and the particulate protein thus extracted was assayed using the Lowry test (Lowry *et al.*, 1951).

Litter decomposition rates were determined by calculating the dry weight remaining as a percentage of the initial pre-leached dry weight. These data were then normalized by the use of an arc-sine transformation and then tested for significant fit with the exponential model (Petersen and Cummins, 1974; Short *et al.*, 1984).

The functional feeding groups of the macroinvertebrate taxa encountered in the litter bags were determined by examination of the gut contents and by consultation with colleagues.

Results

The litter of *E. viminalis* lost 20% of its initial dry weight during leaching; the pine litter lost 7% and the *A. melanoxylon* litter lost only 2%. The leachate from *E. viminalis* litter gave off a strong distinctive odour and was a dark brown colour while the leachates from *Acacia* and pine litter did not smell strongly and were only slightly coloured.

After 90 days a considerable amount of *Acacia* litter remained but only small amounts of pine and eucalypt litter remained. After 156 days, no pine or eucalypt litter remained in the bags at either of the sites while, in contrast, 19.8% of the *A. melanoxylon* litter still remained at Site 1 and 31.8% at Site 2. For all three litter types at the two sites, the exponential model provided a statistically significant fit ($p < 0.05$) (Table 1).

Table 1. Rates of processing of the three litter types at Site 1 and Site 2, and the time (in days) for 50% and 90% of the litter to be processed.

Site	Litter type	Decay coefficient -K	Coefficient of determination (R ²)	T50 in days	T90 in days
1	<i>E. viminalis</i>	.0557	.8782	12.44	41.35
	<i>P. radiata</i>	.0224	.4853	30.94	102.81
	<i>A. melanoxylon</i>	.0073	.7645	94.93	315.48
2	<i>E. viminalis</i>	.0626	.3672	11.07	36.79
	<i>P. radiata</i>	.0185	.3472	37.46	124.49
	<i>A. melanoxylon</i>	.0040	.3907	173.25	575.75

To compare statistically the decay rates, the weight loss data (already arc-sine transformed) were transformed logarithmically, converting the negative exponential curves into straight lines (*viz.* Short *et al.*, 1984). In all cases the linear fit was significant. The slopes were then compared using analysis of covariance (Zar, 1974). The decay rates of eucalypt and pine litter at both sites were equal ($P > .05$) and both differed significantly from the decay rates of *Acacia* litter at both sites ($P < .01$). The decay rates of the *Acacia* litter at both sites were similar ($P > .05$).

The initial protein concentrations of the litter, expressed as percentages of the ash free dry weight, were 8.2% for *E. viminalis*, 7.6% for *P. radiata* and 4.7% for *A. melanoxylon*. As decomposition proceeded, the protein concentration for all three litter types at both sites increased (Figure 1) though, of course, the total protein content of each type of litter decreased over the study period. A two-way analysis of variance (time $\times$ litter type) of the data from days 0, 14, 27, and 48 (after 48 days it was not possible to adequately determine the protein concentration of the eucalypt litter) was carried out. The percentage data were arc-sine transformed. The protein concentrations of all litter types on day 48 were greater ($P < .05$) than those of all litter types on days 0, 14, and 27 which were all similar. The control

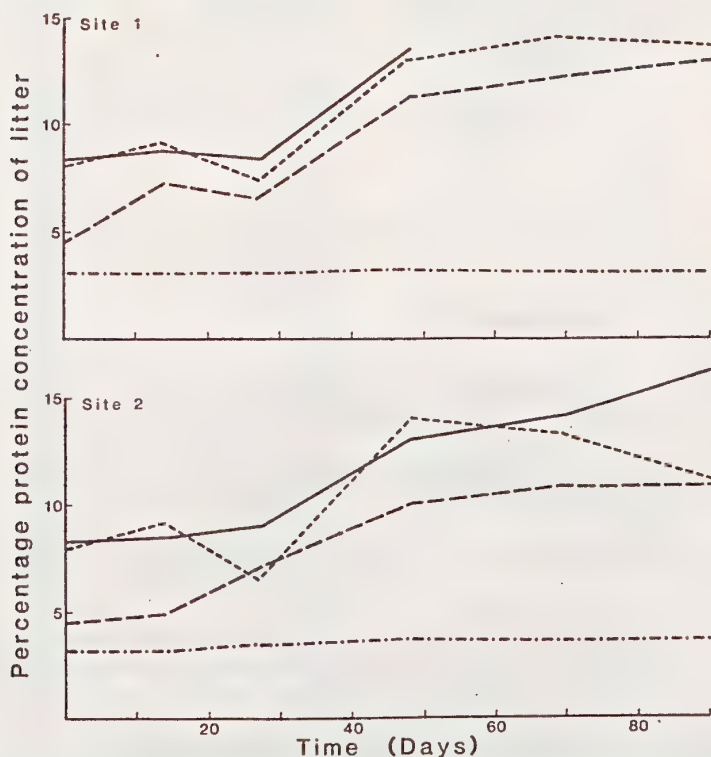


Fig. 1 Protein concentrations of the three types of litter and the control plastic strips at the two sites (— *Eucalyptus viminalis* litter; --- *Acacia melanoxylon* litter; *Pinus radiata* litter; control strips).

Table 2. Functional feeding groups of the invertebrate taxa collected in the litter bags.

Functional feeding group	Order and family	Taxon	Representation of taxon in total collection %
Predators	Odonata — Aeschnidae	<i>Austroaeschna</i> sp.	0.02
	Diptera — Ceratopogonidae	<i>Monohela</i> (?) sp.	0.18
		<i>Forcipomyia</i> sp.	0.02
	Trichoptera — Hydrobiosidae	<i>Ptychobiosis nigrita</i>	0.05
		<i>Koetonga clivicola</i>	0.17
		<i>Apsilochorema obliquum</i>	0.02
		<i>Taschorema kimminsi</i>	0.01
		<i>Taschorema rugulum</i>	0.01
		unident.sp.1	0.07
		unident.sp.2	0.01
Scrapers and grazers	Ephemeroptera — Baetidae	<i>Baetis</i> sp.	0.02
	Plecoptera — Gripopterygidae	<i>Illiesoperla australis</i>	0.32
		<i>Riekoperla tuberculata</i>	0.26
	Coleoptera — Helminthidae	<i>Austrolimnius</i> sp.	0.10
		<i>Notriolus quadriplagiatus</i>	0.11
Collectors	Ephemeroptera — Siphonuridae	<i>Coloburiscoides</i> sp.	1.75
	Coleoptera — Helodidae	<i>Cyphon</i> sp.	2.00
		<i>Byrrhocryptus</i> sp.	0.18
	Diptera — Simuliidae	<i>Austrosimulium mirabile</i>	0.49
	— Dixidae	unident.sp.	0.10
	— Chironomidae		
	— Tanypodinae	sp.108E*	0.03
	— Podonominae	sp.112E* <i>Podonomus</i> sp.	0.03
	— Orthocladinae	sp.10E*	0.49
		sp.12BE*	0.62
		sp.70E*	0.24
		sp.71E*	0.23
		sp.117E*	1.21
		sp.124E*	0.01
		unident.sp.1	0.02
		unident.sp.2	0.02
		unident.sp.3	0.05
		sp.3E*	0.03
		sp.5E*	0.20
		unident.sp.	0.02
	— Athericidae	unident.sp.	0.10
	Trichoptera — Hydropsychidae	<i>Austropsyche</i> sp.	2.17
	— Leptoceridae	<i>Condocerus paludosus</i>	0.01
	— Helicophidae	<i>Alloecella grisea</i>	0.44
	— Conoesucidae	unident.sp.	0.37
Shredders	Amphipoda — Eusiridae	<i>Pseudomoera fontana</i>	66.50
	Ephemeroptera — Leptophlebiidae	<i>Atalonella</i> sp.1	14.42
		<i>Atalonella</i> sp.2	0.03
	Diptera — Tipulidae	sp.1*	0.23
		sp.10*	0.22
		sp.17*	0.20
		sp.29*	0.11
		sp.35*	0.06
		sp.44* <i>Helius</i> sp.	0.03
	Trichoptera — Calocidae	<i>Coenota plicata</i>	5.96

*voucher label of taxa deposited in the National Museum of Victoria, Melbourne

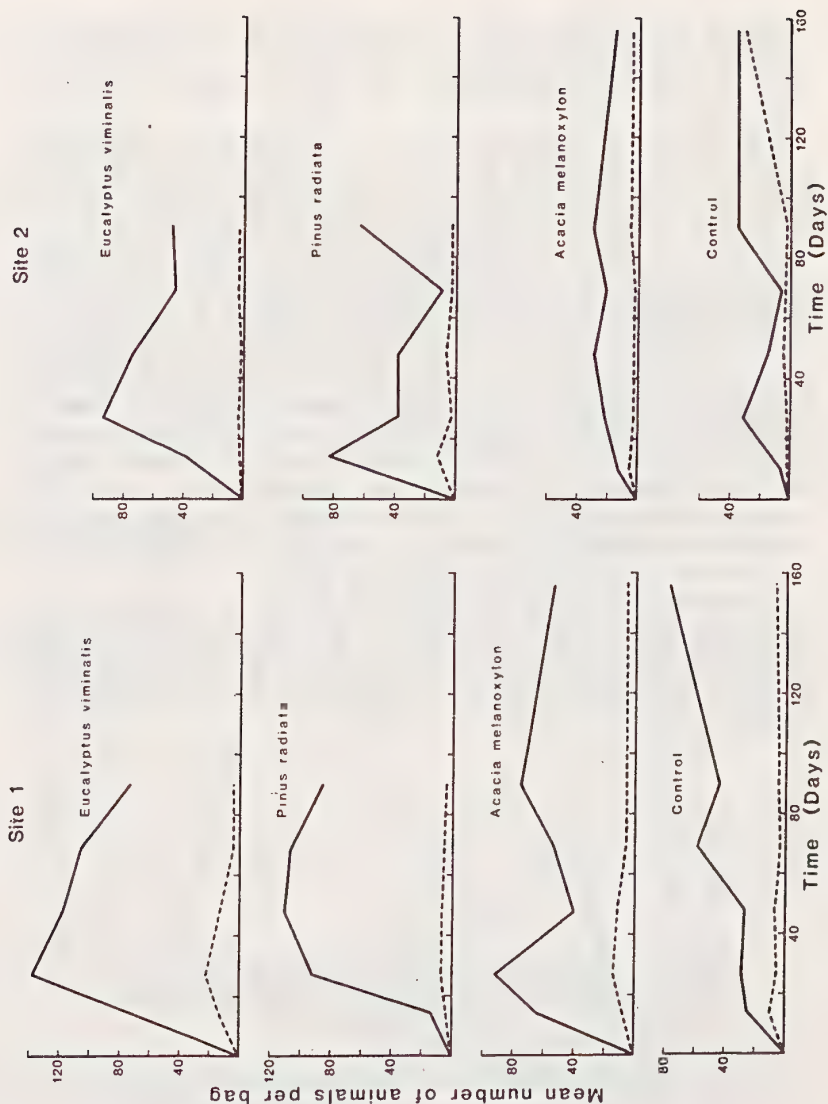


Fig. 2 Mean number of shredders and collectors on the four types of litter at sites 1 and 2 (———— shredders; ----- collectors).

litter proteins were significantly lower than those of all other litter types while the protein concentrations of the eucalypt and pine litter were similar. At both sites respectively, the eucalypt litter and pine litter both had significantly higher protein concentrations than did the *Acacia* litter.

Overall, 10 different taxa of shredders, 5 different taxa of scrapers/grazers, 24 different taxa of collectors and 10 different taxa of predators were collected from the litter bags (Table 2). The numerically dominant

species in all litter bag types at both sites were, in decreasing order, the shredders *Pseudomoera fontana* (Amphipoda), *Atalonella* sp. 1 (Ephemeroptera, Leptophlebiidae) and *Coenota plicata* (Trichoptera, Calocidae).

The densities of shredders colonizing the three litter types and the controls were consistently greater at Site 1 than at Site 2 over the experimental period (Figure 2 and three-way ANOVA of sites $\times$ litter type $\times$ time for 14-90 days, calculated $F_{1,39} = 55.94$ compared with $F_{0.05,1,39} = 5.42$, Site 1 > Site 2, $p < 0.001$). The densities of shredders on the three litter types were greater ($p < 0.05$) than the densities on the controls but they did not differ significantly between the three litter types. Collectors on the three litter types and the controls consistently formed the next most abundant functional feeding group, followed by scrapers and then predators. In the pine and eucalypt litter bags at both sites, the invertebrate abundance peaked in the first two to three weeks (Figure 3) and then declined with the corresponding decline in the amount of litter in the bags. However, with the exception of eucalypt litter at Site 2, the density of macroinvertebrates (number of animals per gram ash free dry weight of litter remaining) increased on the pine and eucalypt litter until the litter was completely broken down (Figure 4).

In contrast, the invertebrate abundance on the *A. melanoxylon* litter and control plastic strips rose steadily, but slowly, over the experimental period (Figures 3,4). This low rate of increase in invertebrate abundance on the *A. melanoxylon* litter is consistent with the low breakdown rate of this type of litter.

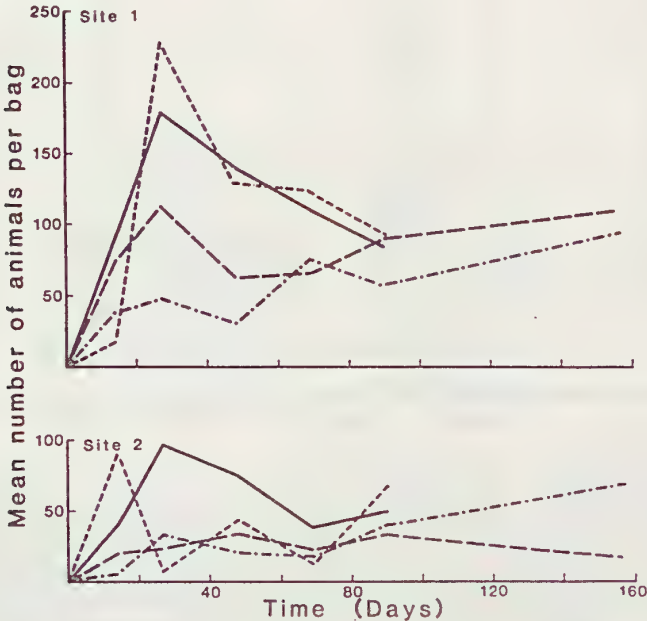


Fig. 3 Mean numbers of macroinvertebrates per bag for the four litter types at the two sites (Legend as for Figure 1).



Fig. 4 Mean number of macroinvertebrates per gram ash free dry weight of litter remaining at the two sites (Legend as for Figure 1).

For all three litter types, the number of taxa of invertebrates peaked relatively early during the decomposition phase (i.e. maximum numbers were reached by day 27); for the control, on the other hand, the maximum number of taxa occurred at day 69 (Figure 5). The number of taxa for all three types of litter at both sites was comparable in the early phase: in the later phase comparison was not possible because much of the litter had decomposed.

The species richness of each litter bag over the period from 14 to 90 days was greater at Site 1 than at Site 2 (Figure 5 and three way ANOVA of site $\times$

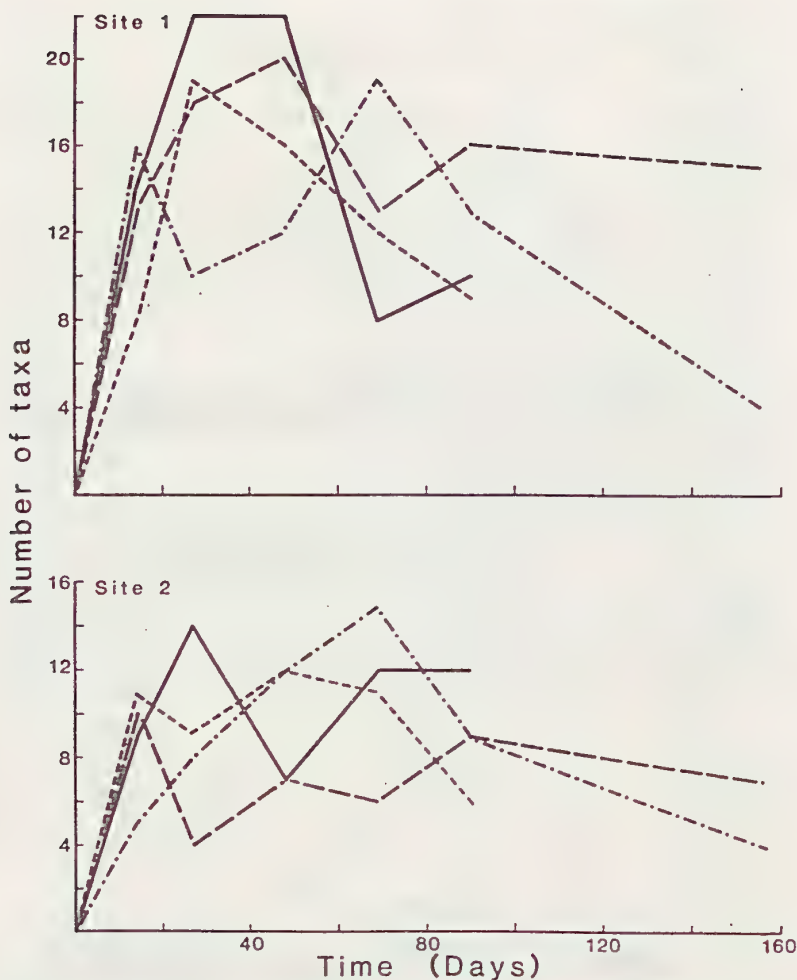


Fig. 5 Species richness of macroinvertebrates colonizing the litter bags at the two sites (Legend as for Figure 1).

species $\times$ time, $F_{1,35}$ ratio for sites = 25.19 compared with $F_{0.0005,1,35} = 14.7$, $p < 0.0005$). The differences between sites were largely accounted for by the greater species richness of non-shredders at Site 1 (chironomid larvae (Diptera) and hydrobiosid larvae (Trichoptera)).

Discussion

The weight loss due to leaching of *E. viminalis* leaves (20% of initial dry weight) is consistent with values reported for other *Eucalyptus* species. For example, corresponding figures of 22-25% dry weight loss have been reported for *E. globulus* leaves (Hart and Howmiller, 1975; Wenner and Busath, 1977) and 22-24% for *E. obliqua* leaves (Barmuta, 1978).

Similarly, Briggs and Maher (1983) reported an initial dry weight loss of 12.1% due to leaching after 112 hours at 15°C and 22.3% after 120 hours at 26°C for *E. camaldulensis* leaves. In contrast, however, relatively low leaching losses of 6.4% after 24 hours and 8% after 48 hours (both at 18°C) were reported by Blackburn and Petr (1979) for *E. regnans* leaves. The differences are no doubt attributable to interspecific differences in the leaves and to differences in the experimental conditions.

Weight losses due to leaching were much lower for *P. radiata* and *A. melanoxylon* litter than for the *E. viminalis* litter. Low leaching losses have, in fact, been reported previously for pine needles (Nykqvist, 1959, 1961; Short *et al.*, 1980). The low leaching loss for *Acacia melanoxylon* litter may be due to the fact that the leaves are actually modified petioles

Table 3. Decomposition characteristics of *Eucalyptus* leaf litter in freshwater systems.

Species	Locality of study	Decay Coeff -icient K	T50 (days)	Processing category of Petersen and Cummins (1974)	Investigators
<i>Eucalyptus globulus</i>	Refugio Creek, California, U.S.A.	.00836	83	medium	Hart & Howmiller 1975; Wenner & Busath 1977
<i>Eucalyptus globulus</i>	Santa Cruz Island stream, California, U.S.A.	.00435	159	slow	as above
<i>Eucalyptus obliqua</i>	Tookayelta creek, S.A.	n.d.	54	medium	Barmuta 1978
<i>Eucalyptus regnans</i>	Cement Creek, Victoria	n.d.	83-86	medium	Blackburn and Petr 1979
<i>Eucalyptus blakelyi</i>	Commissioners Waters, N.S.W.	n.d.	68-82	medium	Pidgeon and Cairns 1981
<i>Eucalyptus*</i> <i>camaldulensis</i>	Hadera River, Israel	.021	33	fast	Herbst and Reice 1982
<i>Eucalyptus</i> <i>camaldulensis</i>	Daliya River, Israel	.036	19.3	fast	as above
<i>Eucalyptus</i> <i>camaldulensis</i>	Lower Tanninim River, Israel	.043	16.1	fast	as above
<i>Eucalyptus</i> <i>camaldulensis</i>	Murrumbidgil swamp, N.S.W.	.007	99	medium	Briggs and Maher 1983
<i>Eucalyptus</i> <i>viminalis</i>	Unnamed trib- utary of Little River, Vic.	.0557 .0626	12 11	fast fast	This study This study

*wrongly named *Eucalyptus rostrata*
n.d. = not determinable

Table 4. Decomposition characteristics of conifer leaf litter in streams

Species	Locality of study	Decay Coeff- -icient K	T50 (days)	Processing category of Petersen and Cummins (1974)	Investigators
<i>Pseudotsuga menziesii</i> and <i>Tsuga heterophylla</i>	Watershed 10, Oregon, U.S.A.	.0025	277	slow	Sedell <i>et al.</i> 1975
"	Mack Creek, Oregon, U.S.A.	.0131	53	medium	Sedell <i>et al.</i> 1975
<i>Pseudotsuga menziesii</i>	Cascade Mount- ains, Oregon, U.S.A.	.00573- .00439	121-158	medium- slow	Triska and Sedell 1976
"	Flynn Creek, Oregon, U.S.A.	.0083	83.5	medium	Triska and Buckley 1978
"	Needle Branch, Oregon, U.S.A.	.0089	77.9	medium	Triska and Buckley 1978
"	Cascade Mount- ains Experi- mental streams, Oregon, U.S.A.	.0041 .0045	169 154	slow slow	Sedell <i>et al.</i> 1975
"	Mack Creek, Oregon, U.S.A.	.0100	69.3	medium	Sedell <i>et al.</i> 1975
"	Watershed 10, Oregon, U.S.A.	.0018	385	slow	Sedell <i>et al.</i> 1975
<i>Larix decidua</i>	Lutzel, Jura Mountains, Switzerland (hard water)	.006	115.5	medium	Rosset <i>et al.</i> 1975
"	Lussel, Jura Mountains, Switzerland, (hard water)	.007	99	medium	Rosset <i>et al.</i> 1982
"	Ibach, Black Forest, West Germany (soft water)	.0046	150.7	slow	Rosset <i>et al.</i> 1982
"	Schwarzenbache, West Germany (soft water)	.0019	365	slow	Rosset <i>et al.</i> 1982
<i>Picea abies</i>	Lutzel, Jura Mountains, Switzerland (hard water)	.0015	462	slow	Rosset <i>et al.</i> 1982

Table 4 Cont.

"	Lussel, Jura Mountains, Switzerland (hard water)	.0014	433.1	slow	Rosset <i>et al.</i> 1982
"	Ibach, Black Forest, West Germany (soft water)	.0015	462	slow	Rosset <i>et al.</i> 1982
"	Schwarzenbache, West Germany (soft water)	.0014	433.1	slow	Rosset <i>et al.</i> 1982
<i>Pinus resinosa</i>	Unnamed tributary of Nith River, Ontario, Canada	.00298	232.5	slow	Bärlocher <i>et al.</i> 1978
<i>Pinus ponderosa</i>	Little Beaver Creek, Colorado, U.S.A.	.0038	182.4	slow	Short <i>et al.</i> 1980
<i>Pinus radiata</i>	Unnamed tributary of Little River, Victoria	.0224 .0185	31 38	fast fast	This study This study

(phyllodes) with a relatively high proportion of thick-walled cells and a high fibre content.

Comparisons of the decomposition rates of different types of litter in streams must be made with caution as there may be great differences between investigations with respect to methodology, seasonal timing and study duration. Decomposition rates may also vary with type of habitat (e.g. Mutch *et al.*, 1983) and type of stream (Sedell *et al.*, 1975; Rosset *et al.*, 1982; Herbst and Reice, 1982). Nevertheless, for the types of leaves used in this study, a comparison of breakdown rates with those reported elsewhere is instructive (Table 3). In general, *Eucalyptus* leaf litter belongs to the 'fast' or 'medium' processing categories of Petersen and Cummins (1974). The only recorded exception is that of *E. globulus* litter from a stream on Santa Cruz Island, California (Hart and Howmiller, 1975; Wenner and Busath, 1977). The very slow decomposition rate reported for *E. globulus* may arise because its leaves have a thick cuticle, are glaucous and have a relatively high oil content whereas the more rapidly decomposing leaves of *E. viminalis* and *E. camaldulensis* are not markedly glaucous and have a relatively low oil content (Penfold and Willis, 1961).

The high decomposition rates, expressed in terms of -K, of *E. viminalis* litter (0.0557, 0.0626) are high in relation to those reported in the literature. Short *et al.* (1984) have reported a -K of 0.0619 for *Celtis laevigata* in a Texan stream and regard this as being among the highest -K values yet recorded.

The decomposition rates of *P. radiata* needles found in this study are the fastest so far recorded for any gymnosperm leaf litter (Table 4). Such high rates are surprising in view of the results of Bärlocher *et al.* (1978),

and Bärlocher and Oertli (1978) who found that conifer needles contain substances which inhibit the build-up of aquatic hyphomycetes — a process deemed normal in the conditioning of leaf litter (Anderson and Sedell, 1979). It is also possible that the high decomposition rate of the pine litter may have been due to broken needles being lost through the relatively large mesh of the bags. The decomposition rates of the phyllodes of *A. melanoxydon* differed between sites, being faster at Site 1 than at Site 2, indicating that this species can be placed in either the 'medium' or 'slow' processing categories of Petersen and Cummins (1974). The relatively slow breakdown may be related to the high tannin content, the relatively high amount of thick-walled cells and the high lignin content of *Acacia* phyllodes. Mellilo *et al.* (1982) found a significant inverse linear relationship between decomposition rate and lignin concentration of leaves in the Hubbard Brook forest, U.S.A.

The rapidly decomposing leaves of eucalypt and pine had higher initial protein concentrations than did the *A. melanoxydon* phyllodes. Generally, it appears that there is a positive correlation between the rate of decay of leaves of different species and their initial nitrogen concentration (*viz.* Kaushik and Hynes, 1971; Sedell *et al.*, 1975; Triska *et al.*, 1975; Triska and Sedell, 1976; Hart and Howmiller, 1975; Blackburn and Petr, 1979; Pidgeon and Cairns, 1981). The increase in the protein concentration of decaying leaves, as was found in this study, has often been reported (*e.g.* Kaushik and Hynes, 1971; Triska *et al.*, 1975; Triska and Sedell, 1976; Davis and Winterbourn, 1977) and is held to be due to the increase in microbial biomass (bacteria, aquatic hyphomycetes) on the leaves (Iversen, 1973; Rosset *et al.*, 1982).

The decomposition rates of the leaves in this study appear to be related to the rate of colonization by macroinvertebrates. The latter in turn may be due to the more rapid conditioning of the 'fast' leaves. Shredders comprised the most abundant functional feeding group on the litter, including the plastic strips, at both sites, with the degree of their abundance on a particular type of litter being directly proportional to the decomposition rate of that litter. A similar finding has been reported by Hart and Howmiller (1975), Sedell *et al.* (1975) and Short *et al.* (1980). In contrast, however, both Reice (1978) and Meyer (1980) found no direct relationship between the number of individuals colonizing leaf litter and the rate of decomposition of leaf packs. Similarly, Herbst and Reice (1982) concluded that in the Israeli streams in which they studied leaf decomposition, the colonization rates of all invertebrates were more important in determining the rates of leaf decomposition than were the species richness or the abundances of different functional feeding groups. On the other hand, Barmuta (1978) concluded that the decomposition of *Eucalyptus obliqua* leaf packs in a small South Australian stream was predominantly an abiotic process which did not require the presence of significant numbers of 'macro-shredders'.

In the present study invertebrates began to consume eucalypt leaves almost as soon as they were placed in the stream. This may be the result

of the eucalypt leaves being rapidly conditioned by fungi and bacteria and then consumed by invertebrates, or of the leaves being eaten by invertebrates without any intermediate step of conditioning. Support for the latter suggestion is provided by Anderson and Grafius (1975), who found that the shredder *Lepidostoma quercina* rapidly consumed newly-fallen *Alnus* leaves, and Herbst and Reice (1982), who found that unconditioned leaves of *Acer saccharinum* were rapidly consumed by shredders.

Although the decay rates of the pine needles were relatively rapid there was little evidence of invertebrate feeding until days 48-69. Similarly, Sedell *et al.* (1975) observed that needles of *Pseudotsuga menziesii* and *Tsuga heterophylla* in Oregon streams remained there for 140 days before any noticeable invasion by invertebrates took place. This delay can be explained by the findings of Bärlocher and Oertli (1978) who found that extracts of the needles of *Pinus leucodermus* and *Sequoia gigantea* inhibited the growth of aquatic hyphomycetes while conidiophores of aquatic hyphomycetes did not develop on needles of *Pinus resinosa* in a stream until 130 days (Bärlocher *et al.*, 1978). Such leaves did not exhibit any noticeable invertebrate damage until after 158 days.

Little can be said about the consumption by invertebrates of *Acacia melanoxylon* phyllodes because no evidence of invertebrate feeding on the phyllodes was found until day 156, at which time the experiment was terminated. However, the fact that such a long period elapsed before feeding on these phyllodes commenced suggests that some process similar to that investigated by Bärlocher and Oertli (1978) occurs in these leaves also — possibly due to the high tannin levels or the thick cell walls of these leaves.

This study compared the dynamics of litter decomposition at two sites on the same stream, one in a pine plantation and one in a eucalypt forest. There appears to be little difference in decomposition rates for each litter type between the two sites. Invertebrate species richness and shredder densities of the litter did differ, being lower in the pine plantation than in the eucalypt forest. These preliminary findings suggest that further detailed study should be directed towards determining whether changes in the species of trees in the catchment of a stream can change the species richness and abundance of stream invertebrates.

Acknowledgements

We would like to thank Mr. R. Fry, Manager of Cathedral Valley Softwoods Company for access to the study site; Mr. D. Morton of the Department of Zoology, Monash University, Mr. J. Dean of the Melbourne and Metropolitan Board of Works, Ms C. Yule of the Royal Melbourne Institute of Technology, Mr. J. Blyth of the Survey Department, National Museum of Victoria for assistance in the identification of many of the macroinvertebrates; and Ms T. McConnell, Ms P. Coates and Mr D. Morton for assistance in the preparation of the manuscript.

References

- Allen, S.E., Grimshaw, H.M., Parkinson, J.A. and Quarmby, C. (1974). 'Chemical Analysis of Ecological Materials.' (Blackwell, Oxford).
- Anderson, N.H. and Graftus, E. (1975). Utilization and processing of allochthonous material by stream Trichoptera. *Verh. Internat. Verein. Limnol.* 19: 3083-3088.
- Anderson, N.H. and Sedell, J. (1979). Detritus processing by macroinvertebrates in stream ecosystems. *Ann. Rev. Entomol.* 24: 351-377.
- Bärlocher, F. and Oertli, J.J. (1978). Inhibitors of aquatic hyphomycetes in dead conifer needles. *Mycologia*: 70: 964-974.
- Bärlocher, F., Kendrick, B. and Michaelides, J. (1978). Colonization and conditioning of *Pinus resinosa* needles by aquatic hyphomycetes. *Arch. Hydrobiol.* 81: 462-474.
- Barmuta, L.A. (1978). The decomposition of *Eucalyptus obliqua* leaf packs in small stream ecosystems. B.Sc. Honours Thesis, University of Adelaide, Australia.
- Blackburn, W.M. and Petr, T. (1979). Forest litter decomposition and benthos in a mountain stream in Victoria, Australia. *Arch. Hydrobiol.* 86: 453-498.
- Briggs, S.V. and Maher, M.T. (1983). Litter fall and leaf decomposition in a river red gum (*Eucalyptus camaldulensis*) swamp. *Aust. J. Bot.* 31: 307-316.
- Davis, S.F. and Winterbourn, M.J. (1977). Breakdown and colonization of *Nothofagus* leaves in a New Zealand stream. *Oikos*: 28: 250-255.
- Hart, S.D. and Howmiller, R.P. (1975). Studies on the decomposition of allochthonous detritus in two southern California streams. *Verh. Internat. Verein. Limnol.* 19: 1665-1674.
- Herbst, G. and Reice, S.R. (1982). Comparative leaf litter decomposition in temporary and permanent streams in semi-arid regions of Israel. *J. Arid Environments* 5: 305-318.
- Hynes, H.B.N. and Hynes, M.E. (1975). The life histories of many of the stoneflies (Plecoptera) of south-eastern mainland Australia. *Aust. J. Mar. Freshw. Res.* 26: 113-153.
- Iversen, T.M. (1973). Decomposition of autumn-shed beech leaves in a springbrook and its significance for the fauna. *Arch. Hydrobiol.* 72: 305-312.
- Kaushik, N.K. and Hynes, H.B.N. (1968). Experimental study of the role of autumn-shed leaves in aquatic environments. *J. Ecol.* 56: 229-243.
- Kaushik, N.K. and Hynes, H.B.N. (1971). The fate of the dead leaves that fall into streams. *Arch. Hydrobiol.* 68: 465-515.
- Lake, P.S. (1982). The 1981 Jolly Award Address 'Ecology of the macroinvertebrates of Australian upland streams — a review of current knowledge'. *Bull. Aust. Soc. Limnol.* 8: 1-15.

- Lowry, O.H., Rosebrough, N.J., Farr, A.L. and Randall, J.R. (1951). Protein measurement with Folin phenol reagent. *J. biol. Chem.* 193: 265-275.
- Mellilo, J.M., Aber, J.D. and Muratore, J.F. (1982). Nitrogen and lignin control of hardwood leaf litter decomposition dynamics. *Ecology* 63: 621-626.
- Meyer, J.L. (1980). Dynamics of phosphorus and organic matter during leaf decomposition in a forest stream. *Oikos* 34: 44-53.
- Mutch, R.A., Steedman, R.J., Berte, S.B. and Pritchard, G. (1983). Leaf breakdown in a mountain stream: a comparison of methods. *Arch. Hydrobiol.* 97: 89-108.
- Nykvist, N. (1959). Leaching and decomposition of litter. II. Experiments on needle litter of *Pinus silvestris*. *Oikos* 10: 212-224.
- Nykvist, N. (1961). Leaching and decomposition of litter. IV. Experiments on needle litter of *Picea abies*. *Oikos* 12: 264-279.
- Penfold, A.R. and Willis, J.L. (1961). 'The Eucalypts. Botany, Cultivation, Chemistry and Utilization.' (Leonard Hill (Books) Ltd., London. Interscience Publishers Inc. New York.)
- Petersen, R.C. and Cummins, K.W. (1974). Leaf processing in a woodland stream. *Freshwat. Biol.* 4: 343-368.
- Pidgeon, R.W.J. and Cairns, S.C. (1981). Decomposition and colonisation by invertebrates of native and exotic leaf material in a small stream in New England (Australia). *Hydrobiologia* 77: 113-127.
- Reice, S.R. (1978). The role of detritivore selectivity in species-specific litter decomposition in a woodland stream. *Verh. Internat. Verein. Limnol.* 20: 1396-1400.
- Rosset, J., Bärlocher, F. and Oertli, J.J. (1982). Decomposition of conifer needles and deciduous leaves in two Black Forest and two Swiss Jura streams. *Int. Revue ges. Hydrobiol.* 67: 695-711.
- Sedell, J.R., Triska, F.J. and Triska, N.S. (1975). The processing of conifer and hardwood leaves in two coniferous forest streams: 1. Weight loss and associated invertebrates. *Verh. Internat. Verein. Limnol.* 19: 1617-1627.
- Short, R.A., Canton, S.P. and Ward, J.V. (1980). Detrital processing and associated macroinvertebrates in a Colorado mountain stream. *Ecology* 61: 727-732.
- Short, R.A., Smith, S.L., Guthrie, D.W. and Stanford, J.A. (1984). Leaf processing rates in four Texas streams. *J. Freshwat. Ecol.* 2: 469-473.
- Spain, A.V. (1973). Litter fall in a New South Wales forest: a multivariate comparison of plant nutrient element status and return in four species. *J. Appl. Ecol.* 10: 527-556.
- Triska, F.J., Sedell, J.R. and Buckley, B. (1975). The processing of conifer and hardwood leaves in two coniferous forest streams: II. Biochemical and nutrient changes. *Verh. Internat. Verein. Limnol.* 19: 1628-1639.
- Triska, F.J., and Sedell, J.R. (1976). Decomposition of four species of leaf litter in response to nitrate manipulation. *Ecology* 57: 783-792.

- Triska, F.J. and Buckley, B.M.** (1978). Patterns of nitrogen uptake and loss in relation to litter disappearance and associated invertebrate biomass in six streams of the Pacific Northwest, U.S.A. *Verh. Internat. Verein. Limnol.* **20**: 1324-1332.
- Wenner, A.M. and Busath, A.L.** (1977). Species differences in breakdown of tree leaves in streams — significance for decomposition of stream communities. California Water Resource Center, University of California, Davis, Report No. **39**, 1-29.
- Williams, W.D. and Wan, H.F.** (1972). Some distinctive features of Australian inland waters. *Water Res.* **6**: 829-836.
- Zar, J.H.** (1974). 'Biostatistical Analyses.' (Prentice-Hall Inc., Englewood Cliffs, New Jersey, U.S.A.)

COMPARISON OF TWO NET EMPTYING FREQUENCIES IN THE ASSESSMENT OF DRIFT SAMPLING AS A POTENTIAL BIOLOGICAL MONITORING TOOL

by Maryanne E. McKaige

Chisholm Institute of Technology, Caulfield East, Victoria, Australia, 3145
Current address: 33 Howley Cres., Anula, N.T., 5793

Abstract

A practical impediment to the potential of drift as a biological monitoring tool is the need for frequent net emptying over a 24-hour period to prevent clogging and subsequent reduction in sampling efficiency. The work presented in this paper attempted to determine whether results from a more acceptable 12-hour net emptying interval could provide any results meaningful to a biological monitoring programme, despite the effects of clogging. This was done by comparing results of 2- and 12-hour net emptying intervals at a single site on an Australian high mountain stream. Over 40% more invertebrates were collected throughout a 12-hour period when nets were emptied 2-hourly than when emptied after 12 hours. However, relative abundance and diversity of invertebrate families were not significantly different. Comparison of relative abundance data of drift from different sites in a macroinvertebrate monitoring programme may therefore contribute to water quality assessment.

Introduction

Biological monitoring of lotic systems is increasingly being seen as an important method in assessing human impacts on flowing waters, and in elucidating the natural cycles and processes occurring within them (Chandler, 1970; Hawkes, 1979; Tittizer and Kothe, 1979; Campbell, 1982; Campbell *et al.*, 1982). This is largely because biological communities act as continuous monitors of the water in which they live (Campbell, 1981, 1982) and reflect in their structure the least favourable condition of the water over a prolonged period. By contrast, chemical samples can only indicate water quality at the time the sample was taken, allowing pollutant episodes to pass unrecorded.

A number of sampling techniques have gained popular use in biological monitoring programmes, with a particular technique usually being chosen with regard to river and substrate type and the information being sought. The suggestion that macroinvertebrate drift sampling may be a potentially useful tool for 'relatively cheap and easy ... biological monitoring in lotic systems' (Arthington and Conrick, 1981) is therefore interesting for several reasons. The first is that although the phenomenon of macroinvertebrate drift has been extensively researched (eg. Waters, 1965, 1969, 1972; Elliott, 1969; Muller, 1974; Bailey, 1981; Graesser and Lake, 1984), it has rarely been used specifically to identify effects of human impact on streams. Secondly, the relationship between invertebrates found in the drift and the benthic fauna is far from clear

(Elliott, 1969; Waters, 1972; Stoneburner and Smock, 1979). While Arthington and Conrick (1981) and Arthington *et al.* (1982) found the drift 'fauna' to be indicative of gross organic pollution, such clear demonstration of pollution cannot be assumed to follow for other pollutants and different concentrations of them. Swain and White (1985) experienced difficulties in explaining drift behaviour in the King River, Tasmania, as a result of heavy metal pollution.

A further point which needs to be considered in the evaluation of the usefulness of drift sampling as a biological monitoring tool is the practical problem of frequent net emptying. Drift nets are generally operated for 24 hours so that diel, largely nocturnal, peaks in drift density (eg. Chaston, 1968; Bishop, 1969; Muller, 1974; Bailey, 1981, Graesser and Lake, 1984) are included in the sample. Under most circumstances drift nets would become clogged within the 24-hour period due to a build up of algae and fine particulate organic matter, and subsequent backwash would reduce collecting efficiency (Waters, 1969; Elliott, 1970). Net clogging has generally not been a problem for drift workers in the past since investigations have focused on drift as a phenomenon, and samples have been collected and nets cleaned sometimes hourly over 24 hours at a single site in order to locate drift peaks.

Drift peaks are, however, of little importance to biological monitoring, which usually relies on the comparison of entire samples from different sites to provide relevant answers. If quantitative or semi-quantitative drift data are required in a monitoring programme the investigator must determine how rapidly the nets will become clogged and clean them accordingly. This could present serious problems if the frequency of net attendance is calculated to be half hourly and a large number of sites must be sampled, as they often are in monitoring programmes. Furthermore, for comparability, drift samples really need to be taken simultaneously at different sites due to the influence of factors such as flow rate (Minshall and Winger, 1968; Pearson and Franklin, 1968; Waters, 1969; Radford and Hartland-Rowe, 1971), temperature (Waters, 1969; Muller, 1974), water quality (Waters, 1969) and suspended solids (White and Gammon, 1977), all of which can vary and alter the drift fauna from day to day. Drift sampling may therefore be an impractical technique for biological monitoring requiring quantitative or semi-quantitative data and/or if frequent net attendance is required. Studies requiring only qualitative data are less likely to be affected by drift net clogging, provided this does not result in selective sampling due to backwash or changes in flow rate.

The work presented in this paper addresses the practical problem of frequent net attendance in the context of a biological monitoring programme. Drift was to be sampled at four sites, 20 km apart, along the Thredbo River, Kosciusko National Park, New South Wales, in an attempt to identify changes related to organic pollution (McKaige, 1986). In relation to this, a comparison of net emptying frequencies of two and 12 hours was carried out initially at one site to determine whether samples obtained from the more acceptable 12-

hour interval could provide any worthwhile information. The results of this comparison are presented in this paper.

Methods

The Thredbo River is located in the Kosciusko National Park, New South Wales, and flows through alpine, sub-alpine and montane catchment areas to Lake Jindabyne. The only major human impacts within the national park occur 12-15 km upstream of the present study site (at Thredbo Diggings) and include ski village development, ski slope grooming, a rubbish dump and sewage plant. The sampling site was a riffle approximately 8 m wide with cobble stones and relatively uniform depth (approx. 0.4 m) and flow rate (Table 1). Six drift nets, 180 cm long with an aperture of 10 × 25 cm and mesh size 300 μ m, were secured side by side across the riffle towards the centre of the stream and a few centimetres below the water surface.

Sampling began one and a half hours before sunset and was continued for 12 hours. Three of the nets were emptied every 2 hours, the other 3 after 12 hours. Three nets were then operated for a further 12-hour period during daylight. Samples were preserved in 10% Kahle's solution and in the laboratory were sorted and identified to family, except Oligochaeta and Turbellaria which were not identified beyond class.

Current speeds were measured once, at the commencement of sampling, at the mouth of each net with a propeller type OTT C31 flow meter. Other selected physico-chemical properties were also determined immediately prior to sampling (Table 1). No precipitation was recorded in the catchment during the sampling period.

Table 1. Selected initial physico-chemical properties of the Thredbo River

Date	Temperature (°C)	pH	Conductivity (μ mhos)	Flow rates msec ⁻¹					
				12 hr samples			2 hr samples		
				I	II	III	I	II	III
27/11/82-									
28/11/82	20	6.85	28	.714	.739	.731	.773	.781	.781

Results

Night Samples

During the night, nets emptied at 2-hour intervals collected over 40% more invertebrates than those emptied after 12 hours (Table 2: $X^2=142.60$, $df=27$, $p<0.001$). An increase occurred in all taxonomic groups except the Hydropsychidae, Polycentropodidae, Neurorthidae, Oligochaeta, Dytiscidae and Staphylinidae, where the differences were not significant ($X^2=3.478$, $df=3$, $p>0.3$). However, when the results for each family were expressed in terms of relative abundance (percentages of the totals, Table 2), the total 2-hr and 12-hr samples were not significantly different (Mann-Whitney U test, $U=397.5$, for $n>20$, $z=0.09$, $p>0.464$). There was

also little difference between the total number of families collected by the two methods (32 vs 31).

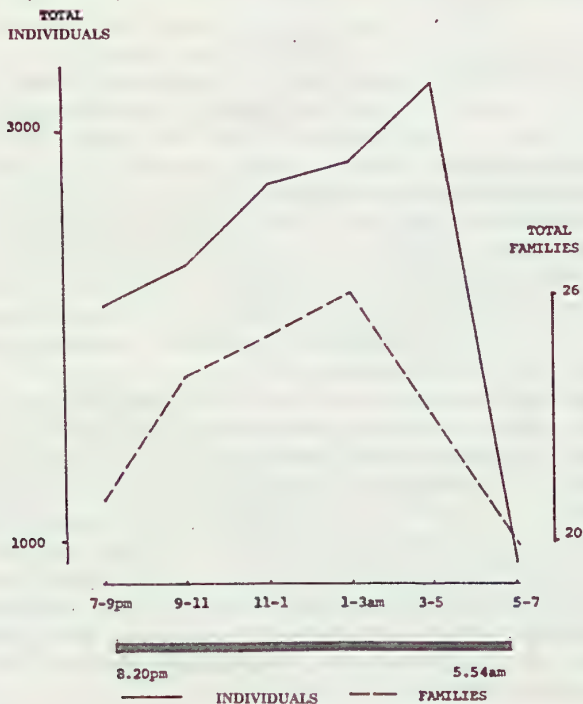


Fig. 1 Two-hourly changes in drift densities of individuals and families.

After the 12-hour period the nets were clogged with fine particulate matter and algae up to about 30 cm from the mouth of the net. This layer was easily dislodged by rubbing the sides of the net together and much of it then passed through the mesh. The 'bloated' appearance of the nets suggested that water flow through them was retarded. Invertebrates, coarse particulate matter and filamentous algae were concentrated towards the bottom of the nets.

The 2-hour changes in total drift density showed a steady increase to a predawn peak, followed by a rapid decline (Figure 1). The number of families represented in the drift peaked slightly earlier.

Day samples

Drift density and diversity were substantially lower during the day than at night (Table 2). The total number of invertebrates collected during the day was nearly equivalent to the 2-hour predawn peak in drift density (3363 vs 3239). Although the composition of the day-time drift fauna was considerably different to that during the night, with a far greater

proportion of Chironomidae and fewer adult Helminthidae and Griptopterygidae in the former, the overall relative abundances of families during the day and the night (total 2 hour samples: Table 2) were not significantly different (Mann-Whitney U test, $U=291$, $n>20$, $z=-1.05$, $p>0.1469$).

Discussion

The 2-and 12-hour sample interval comparisons were only conducted during the night since this is widely recognised as the time of peak drift density (see Introduction) and loss of animals due to backwash would therefore be greater than during the day. The results of the 12-hour day time samples supported this.

The difference in total invertebrates collected overnight by the different sample intervals indicates that sampling efficiency was considerably reduced in the 12-hour sample due to net clogging and backwash (Waters, 1969; Elliott, 1970). However, the fact that the relative abundances of the different families were not significantly altered by the sampling inefficiency is surprising for several reasons. Firstly, it might have been expected that over 12 hours, and with increasingly reduced flows through the nets, some invertebrates already netted would have been able to crawl out. If this were the case, however, the relative abundance of families with more active crawlers, such as mayfly and stonefly nymphs, might have been expected to differ between the 2- and 12-hour samples but this did not occur. Furthermore, under-representation of those invertebrate groups which have a predawn peak might have been anticipated in the 12-hour samples if the nets had poor sampling efficiency at this time; however, relative abundances of such groups were not seriously affected. The results also suggest that stronger swimmers, such as some mayflies and stoneflies, did not selectively avoid the nets.

These findings are interesting because they suggest that by taking drift samples at intervals which are more amenable to biological monitoring programmes (eg. 12 hours), some useful semi-quantitative information may be gained despite the overall reduction in total numbers of invertebrates collected. The data would also be suitable for qualitative studies since the number of taxa were not substantially altered by net clogging over the 12-hour period.

A further potential time and labour saving approach might be to choose to sample for 12 hours either during the day or at night. However, the qualitative differences between samples taken at these two times suggest that 24-hour sampling is preferable, particularly in view of the variations in drift that can be produced by changing environmental conditions.

It should be emphasised that the data presented here were collected under relatively constant conditions i.e. with little change in flow rate or chemical parameters, and do not allow discussion of drift sampling efficiency under different conditions.

Table 2. Results of 2 and 12 hour macroinvertebrate drift sampling.

(Results are totals for 3 nets except for the 12 hour day-time sample where one sample was lost and an average of the remaining 2 added).
FAMILY

FAMILY	7-9pm	9-11	11-1	1-3am	3-5	5-7	TOTALS				PERCENTAGE OF TOTAL			
							2 hour	12 hour	12 hour	12 hour	2 hour	12 hour	12 hour	Day
							Night	Night	Day	Night	Night	Night	Day	Day
Class Insecta														
Order Coleoptera														
Helminthidae	22	27	53	40	19	19	201	141	90	1.41	1.41	1.41	2.68	
Helminthidae (a)	173	322	518	590	702	115	2420	1907	72	17.00	19.02	19.02	2.14	
Helodidae	4	14	16	13	10	3	60	43	2	0.42	0.43	0.43	0.06	
Psephenidae	3	1	3	2	-	-	9	3	2	0.06	0.03	0.03	0.06	
Dytiscidae (a)	-	-	-	-	-	-	-	4	-	-	-	-	-	
Limnichidae (a)	-	-	1	-	-	-	1	-	-	-	-	-	-	
Hydraenidae (a)	-	2	1	1	-	1	5	-	-	-	-	-	-	
Staphylinidae (a)	-	-	-	-	-	-	-	2	-	-	-	-	-	
Order Hemiptera														
Corixidae	-	2	1	2	-	-	5	1	2	0.04	0.01	0.01	0.06	
Order Diptera														
Chironomidae	341	197	199	213	174	100	1224	822	1382	8.61	8.20	8.20	41.09	
Ceratopogonidae	169	91	12	10	10	-	292	172	2	2.06	1.72	1.72	0.06	
Simuliidae	8	12	19	19	13	5	76	30	19	0.53	0.30	0.30	0.56	
Tipulidae	2	1	3	1	1	-	8	4	6	0.06	0.04	0.04	0.18	
Empididae	-	-	-	-	-	1	1	2	-	0.01	0.02	0.02	-	
Athericidae	-	-	-	-	-	-	-	1	-	-	-	-	-	
pupae	118	42	36	43	39	22	300	108	102	2.11	1.08	1.08	3.03	
Order Plecoptera														
Gripopterygidae	231	444	280	590	770	98	2413	1935	293	16.98	19.30	19.30	8.71	
Austroperlidae	7	18	24	22	16	7	94	57	11	0.66	0.57	0.57	3.27	
Eustheniidae	-	-	-	1	1	-	2	1	-	0.01	0.01	0.01	-	
Order Ephemeroptera														
Leptophlebiidae	82	82	106	172	654	65	1161	735	137	8.17	7.33	7.33	4.07	

Baetidae	115	104	93	137	142	39	630	345	221	4.43	3.44	6.57
Caenidae	3	3	1	4	2	1	14	8	6	0.10	0.08	0.18
Order Trichoptera												
Leptoceridae	766	896	1233	894	540	339	4668	3152	728	32.85	31.44	21.6
Conoesucidae	23	14	24	28	21	11	121	106	113	0.85	1.06	3.36
Glossomatidae	3	3	9	5	1	4	25	15	15	0.18	0.15	0.45
Philorheithidae	-	-	-	1	1	-	2	-	2	-	-	0.06
Rhyacophilidae	27	24	40	34	42	9	176	127	36	1.24	1.27	1.07
Hydropsychidae	-	-	1	2	3	2	8	16	5	0.06	0.16	0.15
Ecnomidae	-	-	-	-	2	-	2	2	-	0.01	0.02	-
Helicopsychidae	-	-	-	-	-	-	-	-	1	-	-	-
Polycentropodidae	6	5	2	2	3	1	19	31	2	0.13	0.31	0.06
Order Megaloptera												
Corydalidae	-	1	-	-	-	-	1	-	-	-	-	-
Order Neuroptera												
Neurothidae	-	1	-	-	-	-	1	4	-	0.01	0.04	-
Class Arachnida												
Hydracarina	43	31	46	44	49	33	246	244	91	1.73	2.23	2.71
Class Crustacea												
Cyclopoida	4	3	2	1	3	-	13	12	6	0.09	0.12	0.18
Class Oligochaeta	3	-	3	-	-	2	8	14	18	0.06	0.14	0.54
Class Turbellaria	-	-	-	3	-	-	3	-	-	-	-	-
TOTAL INVERTEBRATES	2153	2340	2726	2874	3239	877	14209	10025	3363			
TOTAL FAMILIES	21	24	25	26	23	20	32	31	24			

(a) = Adults

If relative abundances of taxa can be proved by further research to be reliably unbiased under different conditions, even if drift nets do clog up, then one of the practical problems associated with using drift sampling in biological monitoring may become less significant.

The results and discussion presented here clearly address only a small part of the evaluation of drift sampling as a useful tool in biological monitoring. Other difficulties with the method, such as determining the nature of the relationship between the drift and benthic fauna, need to be studied further before drift sampling can be reliably used in monitoring programmes.

Acknowledgements

The help of the following is gratefully acknowledged: Alan Andersen — field work and advice on the manuscript; Melinda Holt — sorting; Ian Campbell — criticism of the manuscript; Geoff Bruton — statistical analysis; N.S.W. National Parks and Wildlife Service — some financial and practical assistance; Mary Luckin — typing.

References

- Arthington, A.H. and Conrick, D.L. (1981). Alternative approach to biological monitoring: sampling stream drift. *Aust. Soc. Limnol. Newsl.* 19(3): 14.
- Arthington, A.H., Conrick, D.L., Connell, D.W. and Outridge, P.M. (1982). The ecology of a polluted urban creek. *Aust. Water Res. Council Tech. Pap. No. 68*.
- Bailey, P.C.E. (1981). Insect drift in Condor Creek, Australian Capital Territory. *Aust. J. Mar. Freshw. Res.* 32: 111-120.
- Bishop, J.E. (1969). Light control of aquatic insect activity and drift. *Ecology* 50: 371-380.
- Campbell, I.C. (1981). Biology, taxonomy and water quality monitoring in Australian streams. *Water* 8(4): 11-13.
- Campbell, I.C. (1982). Biological water quality monitoring: an Australian viewpoint. In: 'Water Quality Management: Programs and Diffuse Runoff.' (B.T. Hart, ed.) pp.39-66. (Water Studies Centre, Chisholm Institute of Technology and Australian Society for Limnology joint publication).
- Campbell, I.C., Macmillan, L.A., Smith, J.A. and McKaige, M.E. (1982). The benthic communities of the Yarra River and its tributaries. Environmental Studies Program, Ministry for Conservation Publication No. 362.
- Chandler, J.R. (1970). A biological approach to water quality management. *J. Water Pollut. Control Fed.* 69: 415-422.
- Chaston, I. (1968). Endogenous activity as a factor in invertebrate drift. *Arch. Hydrobiol.* 64: 324-334.
- Elliott, J.M. (1969). Diel periodicity in invertebrate drift and the effect of different sampling periods. *Oikos* 20: 524-528.

- Elliott, J.M.** (1970). Methods of sampling invertebrate drift in running water. *Annal. Limnol.* **6**: 133-159.
- Graesser, A. and Lake, P.S.** (1984). Diel changes in the benthos of stones and of drift in a southern Australian upland stream. *Hydrobiologia* **111**: 153-160.
- Hawkes, H.A.** (1979). Invertebrates as indicators of river water quality. In: 'Biological Indicators of Water Quality.' (A. James and L. Evison, eds.) Ch. 2 (John Wiley and Sons, Chichester).
- McKaige, M.E.** (1986). The effects of human impact on the macroinvertebrate communities of the Thredbo River, an Australian high mountain stream. M. App. Sc. Thesis, Chisholm Institute of Technology.
- Minshall, G.W. and Winger, P.V.** (1968). The effects of reduction in stream flow on invertebrate drift. *Ecology* **49**: 580-582.
- Muller, K.** (1974). Stream drift as a chronobiological phenomenon in running water ecosystems. *Ann. Rev. Ecol. Syst.* **5**: 309-323.
- Pearson, W.D. and Franklin, D.R.** (1968). Some factors affecting drift rates of *Baetis* and Simuliidae in a large river. *Ecology* **49**: 75-81.
- Radford, D.S. and Hartland-Rowe, R.** (1971). A preliminary investigation of bottom fauna and invertebrate drift in an unregulated and a regulated stream in Alberta. *J. Appl. Ecol.* **8**: 883-903.
- Stoneburner, D.L. and Smock, L.A.** (1979). Seasonal fluctuations of macroinvertebrate drift in a South Carolina piedmont stream. *Hydrobiologia* **63**: 49-56.
- Swain, R. and White, R.W.G.** (1985). Influence of a metal-contaminated tributary on the invertebrate drift fauna of the King River (Tasmania, Australia). *Hydrobiologia* **122**: 261-266.
- Tittizer, T. and Kothe, P.** (1979). Possibilities and limitations of biological methods of water analysis. In: 'Biological Indicators of Water Quality.' (A. James and L. Evison, eds.) Ch. 4 (John Wiley and Sons).
- Waters, T.F.** (1965). Interpretation of invertebrate drift in streams. *Ecology* **46**: 327-334.
- Waters, T.F.** (1969). Invertebrate drift — ecology and significance to stream fishes. In: 'Symposium on Salmon and Trout in Streams.' (T.G. Northcote, ed.) pp. 121-134. (University of British Columbia, Vancouver).
- Waters, T.F.** (1972). The drift of stream insects. *Ann. Rev. Entomol.* **17**: 253-272.
- White, D.S. and Gammon, J.R.** (1977). The effect of suspended solids on macroinvertebrate drift in an Indiana creek. *Proc. Indiana Acad. Sci.* **86**: 182-188.

A NOTE ON THE DIET OF *GALAXIAS MACULATUS* (JENYNS)
(PISCES, SALMONIFORMES, GALAXIIDAE) IN A CLOSED
SALINE LAKE IN WESTERN VICTORIA

by B.C. Chessman¹ and W.D. Williams²

1. Gippsland Regional Office, Environment Protection Authority of Victoria, P.O. Box 1332, Traralgon, Vic. 3844
2. Department of Zoology, University of Adelaide, G.P.O. Box 498, Adelaide, S.A. 5001.

Abstract

The stomach contents of 114 *G. maculatus* from Lake Corangamite, a closed saline lake in western Victoria (salinity ~30 g l⁻¹), were analysed. Dominant food items were amphipods, isopods and gastropods. Terrestrial arthropods, mainly dipterans, were also important. The small variety of food items reflects the reduced range of prey species in saline lakes.

Introduction

Galaxias maculatus (Jenyns) is a euryhaline galaxiid fish usually inhabiting seaward flowing streams and estuarine and marine waters on or near southern hemisphere land-masses (McDowall and Frankenberg, 1981). In Australia, it occurs in both the south-west and south-east. In addition to populations in typical habitats, land-locked populations occur in both fresh and saline lakes in Victoria (Pollard, 1971a, 1973; Chessman and Williams, 1974; Cadwallader and Backhouse, 1983). Recently, a land-locked population has also been reported from Tasmania (Andrews, 1982).

There is some knowledge of the diet of *G. maculatus* in Australian streams (Butcher, 1946; Richardson, 1985) and in slightly saline lakes (salinity ~4 g l⁻¹: Pollard, 1971b), but nothing has been published on its diet in distinctly saline lakes where the variety of prey species is reduced. The recent statement (Merrick and Schmida, 1984:93) that feeding in this species has been extensively studied does not apply to Australian populations in saline lakes; indeed, rather little is known about the biology of Australian populations of this common fish despite, as McDowall and Frankenberg (1981) pointed out, an apparently substantial number of publications concerning it.

During a series of collections of fish from several Victorian saline lakes, a relatively large number (114 specimens) was obtained from Lake Corangamite which, at the time, had a salinity of ~30 g l⁻¹. Given the lack of knowledge of the diet of the species in saline lakes, the opportunity was taken to examine stomach contents of the Corangamite material. An additional, more general reason for examining the diet of the fish was to see whether it included species also found in lakes with much higher

salinities and lacking fish (viz. the copepods, and the species of ostracod, isopod and gastropod). The results are reported in this note. Lake Corangamite is the most saline inland locality in Victoria from which *G. maculatus* has been recorded (Chessman and Williams, 1974).

Methods

The stomach contents of 114 fish collected on 12 September and 14 October 1971 were investigated. Fish were caught in a 6 mm mesh seine and preserved in 70% ethanol. Length was measured from tip to snout to caudal fork (LCF); stomach contents were removed to a counting tray for examination under a high-power stereomicroscope. Initially, the number of each type of food organism present was noted. A few food items were too broken or digested to be recognised. Numbers were converted to approximate volumes by a technique based on the rapid volumetric method of Hellawell and Abel (1971). The salinity of the lake was estimated from conductivity.

Results

All but five fish contained recognisable stomach contents. Food comprised both aquatic and terrestrial material. Percentage composition by estimated volume of stomach contents of fish of various size classes is given in Table 1. For *Coxiella striata* a whole animal (including shell) was present in only one stomach; otherwise, only parts were found, usually the head and foot regions and opercula. Dietary overlap between fish of different size classes was low; values of Schoener's (1970) overlap index ranged from 0.23 for small cf. large fish, through 0.26 for medium cf. large fish, to 0.44 for small cf. medium fish.

Discussion

As indicated by McDowall (1968), Pollard (1973) and Richardson (1985), *Galaxias maculatus* is a euryphagic carnivore. This statement clearly applies to the Lake Corangamite population also. In that lake, as elsewhere, it feeds on littoral-benthic and planktonic invertebrates, and also takes terrestrial arthropods that have fallen into the water. Predominant food items were amphipods for small fish, gastropods for medium-sized fish, and isopods for large fish. Isopods are presumably too large for small fish to eat readily; gastropods, although smaller than amphipods in terms of the portions eaten, are probably a difficult prey for small fish because of the protection given by the shell. Terrestrial insects are apparently an important food source, at least for fish feeding near shore on windy days (e.g. 14 October).

In comparison with the Lake Modewarre fish studied by Pollard (1973), those in Lake Corangamite ate a much narrower range of food (10 taxa cf. over 20 taxa). This may be partly because of our smaller sample, but undoubtedly it also reflects the lower variety of potential prey species in the more saline lakes (see Williams, 1981). Significantly, the gastropod *Coxiella*, which was apparently avoided by the Lake Modewarre fish,

though present (Pollard, 1973), was an important food item in Lake Corangamite. It thus appears that *G. maculatus* can readily modify its diet to eat less palatable species when easier prey is of restricted

Table 1. Data from analysis of stomach contents of *G. maculatus*.

Food category	Percentage of food in fish of LCF (mm)			
	50-69 (n=81)	70-89 (n=21)	90-110 (n=12)	Total (n=114)
Copepoda				
<i>Calamoecia clitellata</i>	6.3	3.8	0.6	3.9
<i>Mesochra baylyi</i>				
Ostracoda				
<i>Diacypris</i> sp.	1.5	1.3	0.4	1.1
Amphipoda				
<i>Austrochiltonia subtenuis</i>	68.3	16.6	5.9	36.7
Isopoda				
<i>Haloniscus searlei</i>	2.9	2.2	73.6	26.7
Gastropoda				
<i>Coxiella striata</i>	4.9	43.9	5.5	12.9
Terrestrial Arthropoda				
Diptera	11.5	24.5	5.9	12.2
Hemiptera	1.2	1.4	1.2	1.2
Other Insecta	1.7	1.1	0.2	1.1
Arachnida	0.9	1.5	0.3	0.8
Miscellaneous				
Eggs, pupae, plant material	0.9	3.7	6.4	3.3

Percentages listed are of the entire estimated volume of stomach contents examined for each size-class of fish.

n = number of fish examined

availability. The only major invertebrate taxa recorded from Lake Corangamite (Gutteridge, Haskins and Davey Pty Ltd, 1980) and not found in the stomachs of our fish sample were *Cordylophora*, nematodes, rotifers, oligochaetes, *Daphniopsis* and chironomids. The (apparent) absence of the first four of these taxa can be easily explained: for the most part they have soft bodies and if eaten would be difficult to detect. The absence of *Daphniopsis* and chironomid larvae is more difficult to explain. Chironomids were preyed on by *G. maculatus* in Lake Modewarre (Pollard, 1973) and cladocerans are eaten by many small freshwater fish. Perhaps, at the time of sampling, neither chironomids nor *Daphniopsis* were abundant in the lake.

With regard to the more general question examined, it is also clear that, in addition to physiological constraints, predation may be an important matter limiting the extent to which species of highly saline lakes can inhabit water of lower salinity. In Lake Corangamite, however, predation pressure is obviously not so intense as to preclude the occurrence there of at least some species found also at much higher salinities.

Acknowledgements

We thank Dr I.A.E. Bayly for identification of microcrustacea, Dr M.C. Geddes and Mr D.A. Kirton for assistance in the field, and Mr J. Bell and Dr D.A. Pollard for critical comments on a draft manuscript.

References

- Andrews, A.P.** (1982). A Tasmanian landlocked population of the normally diadromous fish *Galaxias maculatus* (Jenyns). *Pap. Proc. R. Soc. Tasm.* 116: 85-90.
- Butcher, A.D.** (1946). 'The Freshwater Fish of Victoria and Their Food.' (Fisheries and Game Department of Victoria, Melbourne).
- Cadwallader, P.L. and Backhouse, G.N.** (1983). 'A Guide to the Freshwater Fish of Victoria.' (Victorian Government Printing Office, Melbourne).
- Chessman, B.C. and Williams, W.D.** (1974). Distribution of fish in inland saline waters in Victoria, Australia. *Aust. J. Mar. Freshw. Res.* 25: 167-172.
- Gutteridge, Haskins and Davey Pty Ltd** (1980). 'The Waters of the Western District Lakes. Addendum to Draft Environment Protection Policy No. W-34B. Technical Appendices.' (Environment Protection Authority of Victoria, Melbourne).
- Hellawell, J.M. and Abel, R.** (1971). A rapid volumetric method for the analysis of the food of fishes. *J. Fish. Biol.* 3: 29-37.
- McDowall, R.M.** (1968). *Galaxias maculatus* (Jenyns), the New Zealand whitebait. *Fish Res. Bull. N.Z.* No. 2 (new series), 1-84.
- McDowall, R.M. and Frankenberg, R.S.** (1981). The galaxiid fishes of Australia (Pisces:Galaxiidae). *Rec. Aust. Mus.* 33: 443-605.
- Merrick, J.R. and Schmida, G.E.** (1984). 'Australian Freshwater Fishes: Biology and Management.' (Merrick, Sydney).
- Pollard, D.A.** (1971a). The biology of a landlocked form of the normally catadromous salmoniform fish *Galaxias maculatus* (Jenyns). I. Life cycle and origin. *Aust. J. Mar. Freshw. Res.* 22: 91-123.
- Pollard, D.A.** (1971b). Faunistic and environmental studies on Lake Modewarre, a slightly saline athalassic lake in southwestern Victoria. *Bull. Aust. Soc. Limnol.* 4: 25-42.
- Pollard, D.A.** (1973). The biology of a landlocked form of the normally catadromous salmoniform fish *Galaxias maculatus* (Jenyns). V. Composition of the diet. *Aust. J. Mar. Freshw. Res.* 24: 281-295.
- Richardson, B.A.** (1985). The impact of forest road construction on the benthic invertebrate and fish fauna of a coastal stream in southern New South Wales. *Bull. Aust. Soc. Limnol.* 10: 65-87.
- Schoener, T.W.** (1970). Non-synchronous spatial overlap of lizards in patchy habitats. *Ecology* 51: 408-418.
- Williams, W.D.** (1981). The limnology of saline lakes in western Victoria. A review of recent studies. *Hydrobiologia* 82: 233-259.

MACROINVERTEBRATE COMMUNITIES IN THE GOULBURN RIVER AND TRIBUTARIES ABOVE LAKE EILDON, VICTORIA

by T.J. Doeg

Biological Survey Department, Museum of Victoria, 71 Victoria Crescent, Abbotsford, Victoria, 3067.

Abstract

A set of ten kick samples was collected in June 1984 at each of 17 sites in four catchments draining into the south-eastern arms of Lake Eildon, Victoria. A total of 176 macroinvertebrate taxa was identified. The majority of the taxa (153, or 85%) were insects, in 7 orders and 42 families. The high diversity and composition of the fauna compared favourably with studies of similar, relatively undisturbed sites in other Victorian river systems.

There were no significant differences between the total number of taxa collected at each site. However, ordination by Detrended Correspondence Analysis (DECORANA) and classification by Two-Way Indicator Species Analysis (TWINSPAN) detected differences between the species composition of sites in agricultural land and those in natural vegetation. The differences seemed to be due to variations in a number of taxa which may prove valuable as indicators of relatively undisturbed stream conditions (e.g. *Atalophlebioides* sp. 1, *Helodidae* sp. 1).

Introduction

This paper presents information on the composition and distribution of aquatic macroinvertebrate communities in rivers draining into the south-eastern arms of Lake Eildon, Victoria. Previously, little or no sampling for benthic invertebrates has been conducted in this region, although data for the La Trobe River (Metzeling *et al.*, 1984; Marchant *et al.*, 1984, 1985) and the Thomson River (Museum of Victoria, unpublished data) to the south, and the Mitta Mitta River (Blyth *et al.*, 1984; Doeg, 1984) to the north are available.

The Study Area and Sampling Sites

The study area (Figure 1) covers the four main catchments leading into the south-eastern arms of Lake Eildon, Victoria (37°15'S, 146°5'E). The rivers draining these catchments are the Big River, the Goulburn River, the Jamieson River and the Howqua River. All four catchments are characterized by small flood plains with steep forested slopes. The rivers have similar substrata, water quality and flow regimes (State Rivers and Water Supply Commission, 1984), and are typical of the transition zone between upland streams with steep gradients and the slower flowing foothill and lowland rivers. The rivers drain catchments composed primarily of Devonian and Silurian marine sedimentary rocks, and receive an annual rainfall of 1000-1400 mm (Land Conservation Council, 1973).

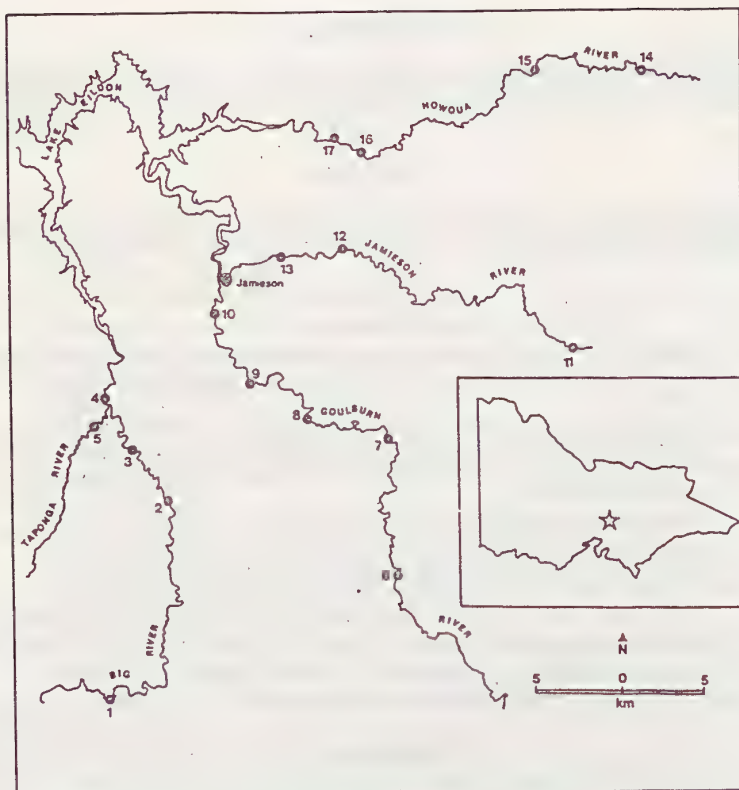


Fig. 1 Location of the study area and sampling sites.

The predominant vegetation in the study area is open mixed-eucalypt woodland. Land use is primarily for tourism and agriculture, cleared and residential land being common along the lower reaches of the Goulburn, Jamieson and Howqua Rivers. Gold mining is still carried out on some tributaries of the Goulburn River, and the Big, Goulburn and Howqua Rivers have been subjected to varying intensities of gold dredging with small one-person floating suction devices (which remove patches of substratum, often to the bedrock, extract the gold and re-deposit the substratum in the stream) over the past ten years.

Seventeen sampling sites were established in the four catchments (Figure 1). Sites were chosen for their accessibility and were matched as far as possible for similarities of flow and substratum composition. The altitudes of the sites ranged from 315 to 560 m above sea level, and all were located in order 4 or 5 segments of the rivers. River width ranged between 6 and 12 m, maximum water depth in the riffles was around 50 cm and average water velocity (measured at 0.2 and 0.8 depths for each sample) was 60-70 cm sec⁻¹. Substratum composition at all sites was predominantly cobble/pebble with varying lesser quantities of sand, boulders and bedrock. Upstream sites on the Goulburn, Jamieson and Howqua Rivers, and all sites on the Big River were located in areas of

undisturbed natural vegetation, while the lower sites were mainly in either cleared agricultural land or developed picnic and camping areas. Exotic vegetation (e.g. willows, blackberries) was common at many of these lower sites.

Methods

Ten kick samples were collected at each site between 17 and 21 June 1984, using a 150 μ m mesh FBA net. Each sample covered an area of 0.03 m² to a depth of 10 cm. Sampling was conducted in riffle sections over a length of river that varied from 30-50 m at each site.

In the laboratory, organic material was separated from inorganic sediment by flotation in a saturated CaCl₂ solution. The organic fraction was retained, a 10% subsample taken and all macroinvertebrates in the subsample were extracted by hand under a stereomicroscope and preserved in 70% alcohol.

Where possible, macroinvertebrates were identified to species using published keys. For groups where taxonomic knowledge was inadequate (a large proportion of the taxa examined), presumptive species were identified according to the voucher collection established by the Biological Survey Department of the Museum of Victoria. The term 'species' will be used in both of the senses above throughout this paper.

Standard community variables (total number and number of species and individuals per sample) were calculated for each site and compared using common statistical procedures. The main comparative analyses between sites were carried out using ordination and classification techniques, described by Gauch (1982). The two programs employed were Detrended Correspondence Analysis (DECORANA) and Two-Way Indicator Species Analysis (TWINSPAN), supplied in the Cornell Ecology Program series and detailed by Hill (1979a,b). Programs were run using a VAX 11/780 computer in the Computer Centre, Monash University.

These techniques have been used successfully to classify macroinvertebrate communities in a large number of English streams (Furse *et al.*, 1984; Wright *et al.*, 1984), and benthic marine communities at Corner Inlet and Nooramunga in Victoria (Museum of Victoria, unpublished data), and appear to have considerable potential in analysing the results of ecological surveys.

Results

Macroinvertebrate Communities

A total of 176 macroinvertebrate taxa was collected from the 17 sampling sites, covering 5 major phyla and 8 classes. The majority (153 or 85% of the total) were insects, in 7 orders and 42 families. A list of the 30 most common taxa with the mean abundance per sample at each site is presented in Table 1. A full list of all taxa and abundances is available on request.

Table 1. List of the 30 most common taxa collected with the mean abundance per sample at each site.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Ephemeroptera																	
Leptophlebiidae																	
<i>Atalophlebioides</i> sp.1	35.1	119.8	72.2	67.4	112.3	72.4	75.3	105.5	1.1	1.0	89.0	54.1	63.5	77.2	3.0		
Baetidae																	
<i>Baetis</i> sp.3	3.1	34.2	20.2	11.0	7.1	1.1	12.2	0.1	5.1	1.1	26.7	6.4	12.2	17.6	13.4	32.9	7.2
Caenidae																	
<i>Tasmanocoenis</i> sp.2	15.0	29.0	39.0	36.0	19.0	34.0	24.0	37.0	9.0	27.0	13.1	30.2	18.0	42.0	2.0	183.0	299.0
Siphonuridae																	
<i>Coloburiscoides</i> sp.1	1.1	6.2	7.0	13.3	1.1	3.1	5.4	6.2	1.0	10.2		3.0	17.3		26.2	26.2	33.7
Plecoptera																	
Gripopterygidae																	
<i>Illiesoperla australis</i>	5.0	2.0	15.0	7.0	7.0	14.0	9.0	9.0	2.0	15.0	22.0		4.0	44.0	15.0	14.0	7.0
<i>Tynotoperla yeoi</i>	3.0	21.0	10.0	25.0	8.0	25.0	26.0	12.0	8.1	25.0	58.1	1.0	13.0	82.1	39.0	9.0	7.0
<i>Riekoperla rugosa</i>	2.0	1.0		1.0	6.0	6.0	3.0		3.0	4.0	29.0	10.0	4.0	10.0	11.0	26.0	7.0
<i>R. karki/williamsi</i>	9.0	1.0		1.0	2.0	14.0	26.0	18.0	68.0	40.0	2.0	23.0	35.0	13.0	50.0	73.0	28.0
<i>Leptoperla</i> spp. ¹	9.0	6.0	10.0	6.0	5.0	8.0	4.0	6.0	12.0	7.0		22.0	3.0	2.0	79.1	56.0	18.0
<i>Dinotoperla fontana</i>	9.0	43.0	12.0	6.0	5.0	20.0	2.0	3.0	19.0	14.0	5.0		3.0	26.0	25.0	11.0	9.0
<i>D. serricauda</i>		5.0	5.0		3.0	11.0	9.0	2.0	34.0	27.0	8.0		8.0	77.2	11.0	4.0	46.0
Trichoptera																	
Glossosomatidae																	
<i>Agapetus</i> sp.1	63.0	53.0	21.0	37.0	65.0	21.0	20.0	5.0	4.0	35.0	19.0	69.0	88.0	95.0	37.0	61.0	49.0
Leptoceridae																	
<i>Notalina</i> spp. ¹	42.0	37.0	35.0	33.0	24.0	70.1	55.0	45.0	7.0		75.1	32.0	14.0	93.0	2.0	5.0	2.0
Hydropsychidae																	
<i>Cheumatopsyche</i> sp.5				1.0			1.0	1.0		4.0		2.0	5.0		28.5	20.1	44.7

¹ *Notalina* spp. represents the abundance of indistinguishable immature forms of both *N. fulva* and *N. bifaria*, and *Leptoperla* spp. refers to both *L. bifida* and *L. kimminsi*.

Table 1. (cont.) List of the 30 most common taxa collected with the mean abundance per sample at each site.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Coleoptera																	
Psephenidae																	
<i>Sclerocyphon striatus</i>																	
Helodidae																	
<i>Helodidae</i> sp.1	7.0	29.0	12.0	20.0	18.0	11.0	29.0	11.0					5.1	3.1	33.1	17.1	16.7
Elmidae																	
<i>Austrolimnius</i> spp.10E	8.0	10.0	6.0	7.0	16.0	6.0	9.0	14.0	26.0	18.0	10.0	20.0	11.0	5.0	8.0		
Diptera																	
Tipulidae																	
<i>Tipulidae</i> sp.4	1.0	1.0	7.0	9.0	22.0	3.0	6.1	9.0	1.0		34.0	18.2	2.0	72.0		1.0	
Chironomidae																	
<i>Rietbia</i> sp.1	80.1	32.0	22.0	28.0	36.0	35.0	13.0	18.0	1.0	15.0	22.0	19.0	33.0	116.1	106.2	16.0	28.0
<i>Rheotanytarsus</i> sp.1	6.0	17.0	7.0	18.0	38.0	21.0	57.0	23.0	13.0	131.0	127.0	15.0	113.0	14.0	74.0	82.0	44.0
<i>Rheocricotopus</i> sp.1	5.0	12.0	2.0	2.0			3.0		2.0	12.0	8.0	13.0	19.0	6.0	37.0	3.0	9.0
nr. <i>Cordites</i> sp.1	10.0	23.0	15.0	7.0	28.0	12.0	40.0	59.0	9.0		11.0	17.0	4.0	44.0	5.0	1.0	
<i>Cricotopus</i> spp.12E	2.0	8.0	7.0	2.0	3.0	6.0	3.0	1.0	7.0	7.0	5.0	2.0	8.0	9.0	34.0	2.0	15.0
? <i>Eukiefferiella</i> sp.1	3.0		4.0	7.0	5.0	1.0	5.0	3.0	7.0	17.0	2.0	1.0	13.0	7.0	1.0	21.0	22.0
nr. <i>Eukiefferiella</i> sp.1	1.0	10.0	4.0		2.0	12.0	12.0	14.0	5.0	8.0	14.0	7.0	15.0	45.0	51.0	7.0	9.0
<i>Abiabetesmyia</i> sp.1	9.0	24.0	21.0	49.0	23.0	15.0	30.0	33.0	6.0		26.0	26.0	4.0	9.0	1.0	2.0	
<i>Podonomopsis</i> sp.1	3.0	17.0	19.0	17.0	10.0	6.0	33.0	24.0	21.0	6.0	16.0	20.0	16.0	13.0	14.0	34.0	6.0
<i>Aphroteniinae</i> sp.18E	3.0	6.0	9.0	14.0	20.0	10.0	10.0	23.0	26.0	10.0	15.0	13.0	6.0	18.0	27.0	18.0	6.0
Oligochaeta																	
	63.0	65.0	36.0	28.0	119.0	55.0	40.0	28.0	97.0	216.0	86.0	23.0	131.4	112.2	311.0	133.0	107.0
Arachnida																	
Acarina sp.																	
		3.0	2.0	7.0	1.0	1.0	6.0	3.0	1.0	8.0	4.0	13.0	2.0	18.0	26.0	12.0	8.0

Within the insects, the most diverse order was the Diptera, with 50 species. The majority of these belonged to the Chironomidae (31 species), with the most common and widespread being *Rheotanytarsus* sp. 1 and *Riethia* sp. 1, the orthoclad nr. *Cordites* sp. 1 and *Ablabesmyia* sp. 1. The remaining dipteran taxa were distributed among the Tipulidae (5 species), Simuliidae (4 species), Empididae (3), Rhagionidae (3), Ceratopogonidae (2), Tabanidae and Blephariceridae (1 species each).

The second most diverse insect order was the Trichoptera (17 families, 41 species), the two most common and widespread species being *Agapetus* sp. 1 (Glossosomatidae) and *Notalina* spp. (Leptoceridae — see footnote in Table 1). All four Australian families of Plecoptera were recorded during the study, comprising 18 species dominated by the two gripopterygid species *Trinotoperla yeoi* and *Riekoperla karki/williamsi* (see Hynes, undated).

The Ephemeroptera was represented by 4 families (15 species) and contributed the two most common insect species collected: *Atalophlebioides* sp. 1 (Leptophlebiidae) and *Tasmanocoenis* sp. 2 (Caenidae). The remaining three insect orders, the Coleoptera (4 families, 24 species), Odonata (3 families, 3 species) and Megaloptera (1 species), contributed no exceptionally common taxa, although the high diversity of the Coleopteran family Elmidae (19 species) is worthy of note.

The non-insect taxa consisted of 17 species of aquatic mites (Arachnida), 3 species of Mollusca, 1 species of Collembola and the higher taxonomic groups of the hydroid Cnidaria and Turbellaria (probably only one species of each). The Oligochaeta (a taxon composed of an unknown number of species) formed the most abundant of any of the taxa collected and were present in relatively high numbers at every site.

Community Variables

Table 2 presents the total number of species and individuals, and the number of species and individuals per sample recorded at each site.

Chi-squared analysis indicated that there were no significant differences among the total number of species collected at each site, implying that the values recorded do not represent a significant deviation from the expected mean of 71.3 species. Similar analysis of the total number of individuals per site (using a logarithmic transformation) revealed significant deviations from the expected mean of 884 individuals per site ($p < 0.001$). One-way analysis of variance of the number of species per sample at each site indicated that there was a significant variation between sites ($F_{16,153} = 3.71$, $p < 0.05$). The Student-Newman-Keuls test (Sokal and Rohlf, 1969) showed sites 11, 14 and 15 had significantly more species per sample than the remaining sites. Sites 1 and 9 had the lowest number of species per sample, and the remaining sites formed a complex set of overlapping groups. Given that each site has a similar total number of recorded taxa, this variation in the number of species per sample suggests that sites with low species density may have a more uneven distribution of taxa among

Table 2. Total number of species and individuals, and the number of species and individuals per sample (with the standard error of the mean), recorded at each site.

Catchment site	Big/Taponga Rivers				Goulburn River				Jamieson River				Howqua River				
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Total no. of species	63	75	69	81	72	78	78	78	66	63	78	65	72	85	74	59	64
Total no. of individuals	554	805	587	710	822	675	758	717	597	836	1005	663	914	1434	1268	1022	1008
Mean no. of species per sample	19.5	25.4	22.9	26.2	25.4	26.5	25.8	25.9	21.1	23.1	27.8	26.3	25.9	35.6	29.9	23.1	26.1
Standard error	1.8	2.1	2.1	3.2	2.0	2.1	2.1	1.4	1.6	1.2	1.3	1.5	2.6	1.5	1.3	1.3	1.0
Mean no. of indiv. per sample	54.3	79.9	57.6	71.0	74.9	67.0	75.0	71.7	59.5	83.5	98.1	65.1	91.0	141.0	126.5	102.0	99.3
Standard error	5.4	9.8	7.6	13.5	8.3	9.7	8.4	8.3	4.8	6.8	10.2	5.7	14.8	13.1	10.0	10.2	8.2

the samples (possibly due to a more heterogeneous substratum) than sites with a higher but more homogeneous species density.

Analysis of variance of the number of individuals per sample at each site revealed significant variations between the sites ($F_{16,153}=5.79$, $p<0.005$). The Student-Newman-Keuls tests showed that sites on the Howqua River clearly had a more abundant fauna than the remaining sites, which formed a non-significant group.

Ordination

A data set, consisting of a list of species abundances at various sites can be seen as occupying an n -dimensional space, where n is the number of species. Each point in the space, representing a site, reflects the species composition at that site. Similar sites will tend to be closer together in the space than dissimilar sites, although this is very difficult to visualise from the raw data, and impossible to display on any one diagram. Ordination techniques attempt to reduce the dimensionality of the original data set so that it can be mapped onto two-dimensional diagrams with minimal loss of the relationship between the sites (Gauch, 1982; Pielou, 1984). In this context, ordination is used to explore potentially interesting patterns in the data, rather than to formally test hypotheses.

Figure 2 presents the data set collected in this study as projected onto only 2 dimensions, following analysis by DECORANA, using the mean abundance of each taxon at each site (logarithmic transformation of the data produced a similar pattern).

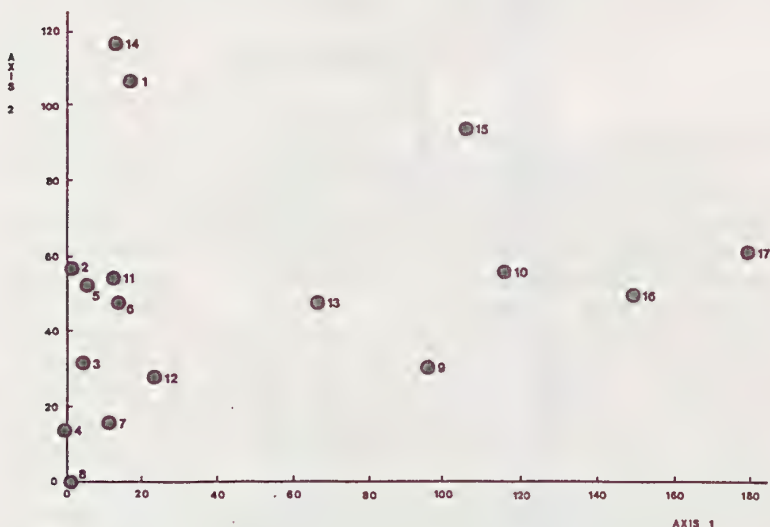


Fig. 2 DECORANA scores along the first two axes for each site.

Along the primary axis (eigenvalue = 0.27), there is a clear division between a group of 11 closely related sites with low axis 1 scores (sites 1, 2, 3, 4, 5, 6, 7, 8, 11, 12 and 14) and a group of six less closely related sites at higher axis 1 scores. The length of the gradient (1.81 units) represents a turnover of about half the community (Hill, 1979a), so that many species were distributed over the entire study area (Table 1). The group of six unrelated sites (9, 10, 13, 15, 16 and 17) represent the lower two sites on the Goulburn River, the lower site on the Jamieson River and the three lower sites on the Howqua River. This distinction between the two major groups of sites does not appear to be the result of differences in altitude, as the lower sites on the Big River are not included. As noted previously, the highest density of riparian housing and agricultural land clearing is located on the lower reaches of these rivers. The larger group of sites with similar low scores on axis 1 includes sites that are generally far less disturbed, retaining natural vegetation along the banks, and with fewer houses and less tourist access. The inclusion of site 8 in this group is somewhat anomalous as it is clearly altered, having a pine plantation along one bank and cleared land along the other. In general, however, this division along axis 1 seems to reflect closely the distribution of the sites that are affected most by human disturbance.

The dissimilarity between the group of 6 disturbed sites may be attributed to the wide range of potential disturbances in the agricultural



Fig. 3 Map of the study area showing site-groups by the DECORANA analysis.

and housing areas. These are likely to be unevenly distributed over the affected area, producing a detectably different community composition at each affected site.

The second axis had a much lower eigenvalue (0.08), but appears to be related to the longitudinal position of the sites in the rivers. In the group of undisturbed sites, upper sites have higher axis scores than lower sites. An arbitrary subdivision into three subgroups can be made, with site 1 and 14 in one group, sites 2, 5, 6 and 11 in a second and the five remaining sites in the third. Displaying these groups on a map of the study area (Figure 3) shows this longitudinal relationship. Further evidence for this conjecture comes from the observation that the axis 2 scores for the group of 10 undisturbed sites (not including site 5) and the distance from the most upstream confluence of first order streams (on a 1:100,000 map) on the appropriate river are highly negatively correlated, ($r = -0.92$, $df=9$, $p < 0.01$), indicating that the further one samples downstream, the lower would be the equivalent axis 2 score.

No further ecological interpretation could be made from the distribution along the third (eigenvalue = 0.04) or fourth (0.03) axes. Hence, while axis 1 of the DECORANA plot appears to divide the sites on the degree of disturbance due to human activity, axis 2 possibly reflects natural longitudinal zonation in the undisturbed sections.

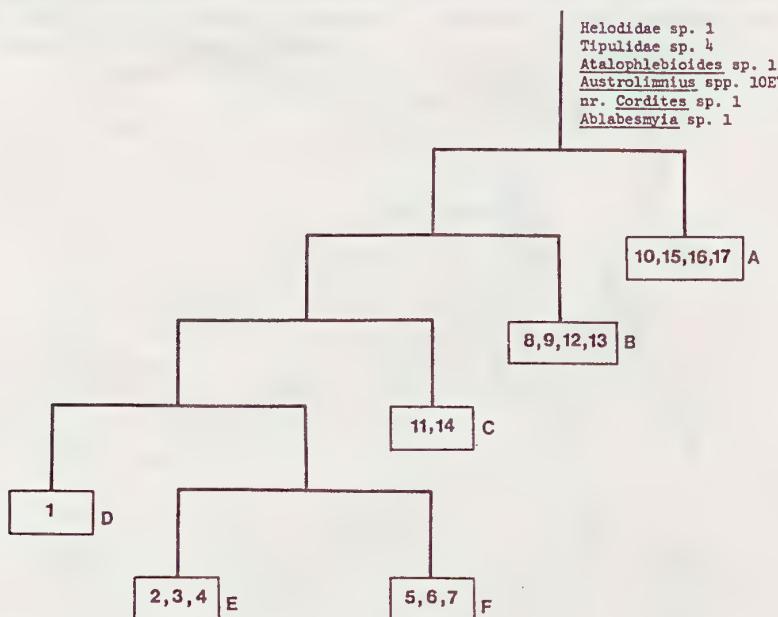


Fig. 4. Classification of sites by TWINSpan. Major indicator species are given for the primary dichotomy.

Classification

Classification techniques assign entities (in this case, the sampling sites) into a series of groups or clusters, each member of the cluster being related by some common variable (e.g. species composition). In this way the relationship between sites, or groups of sites, can be identified, and may then possibly be related to environmental variables.

The dendrogram obtained from the TWINSPLAN analysis is presented in Figure 4. Because of the divisive nature of the TWINSPLAN algorithm, groups of sites are progressively split off on the basis of their dissimilarity from the remaining sites. Hence, the group of sites 10, 15, 16 and 17 (Group A, Figure 4) are seen as distinct from the other 13 sites. This group corresponds, in part, to the sites with high axis 1 scores in the DECORANA plot (Figure 2). The remaining sites with high axis 1 scores (sites 9 and 13) are extracted in the second dichotomy, along with the nearby sites 8 and 12 (Group B). These divisions may also be reflecting the effects of human disturbance, the inclusion of site 8 being intuitively correct, given the disturbance observed at that site. The change in affinity of site 12 from the undisturbed group in the DECORANA analysis, to the disturbed group in this TWINSPLAN analysis seems strange as there is no evidence of gross disturbance at that site. It is, however, just upstream of a large area of cleared land that extends for the remaining length of the Jamieson River to Lake Eildon, and the community at this site possibly receives colonizers from both areas, making it intermediate between the disturbed and undisturbed sites in community composition.

The remaining TWINSPLAN groups again seem to reflect differences between upstream and downstream macroinvertebrate communities, with the upper sites forming a distinct set of groups although the pattern of site relationships differs from the DECORANA analysis (compare Figures 3 and 5). Although the exact patterns along the second DECORANA axis and lower TWINSPLAN dichotomies are somewhat different, the general conclusions are similar.

TWINSPLAN also provides a list of indicator species (those which best characterise the dichotomy) for each division. These are provided for the first division in Figure 4. Hence, Helodidae sp. 1, Tipulidae sp. 4, *Atalophlebioides* sp. 1, *Austrolimnius* sp. 10E, orthoclad nr. *Cordites* sp. 1 and *Ablabesmyia* sp. 1 have the most disjunct distribution between the two halves of the dendrogram, being rare at sites 10, 15, 16 and 17, but widespread at the remaining sites (Table 1).

Discussion

Macroinvertebrate Communities of the Study Area

The total of 176 taxa and mean of around 72 species per site compares favourably with the few studies of similar sites in other Victorian river systems. Metzeling *et al.* (1984) reported totals of 178 and 172 taxa at 17 sites in the Upper LaTrobe catchment in May 1979 and 1980 respectively, using a modified Surber sampler (enclosing 0.05 m²) with the same mesh



Fig. 5 Map of the study area showing site-groups indicated by the TWINSpan analysis.

size as used here, and taking 10 samples per site. At two LaTrobe River sites with similar physical characteristics to sites used in this study, the total taxa collected were 71 and 64 (site 60), and 69 and 59 (site 52) in the two winter samples reported.

Quantitative studies in the Thomson River (Museum of Victoria, unpublished data) revealed that the total taxa collected from a set of 10 samples (using the same methods as above), taken in winter at a similar site to the majority used here, were 66 in 1979 and 68 in 1980. The mean number of species per sample at that site on each occasion were 34 and 35, which is within the range of 19.5-35.6 per sample found in this study (Table 2).

Although differences in the sampling methods and programs tend to obscure the comparisons, the numbers and density of taxa collected in this study can be seen to be of the same order as that reported from fairly undisturbed sites with similar physical characteristics in the foothill sections of other Victorian rivers.

Certainly, the number of taxa is greater than that found in severely disturbed rivers. Doeg (1984) collected less than 30 species at a site on the Mitta Mitta River (site 3A) just downstream of Dartmouth Dam. Similarly, the Museum of Victoria (unpublished data) found fewer than 40 species at a site disturbed by reservoir construction on the Thomson River during winter. Both of these sites were located in areas topographically similar to most of the sites used here.

The species composition recorded at most of the sites appears to be typical of relatively undisturbed sites in the foothill-upland transition zones. The taxa collected are generally similar to those found in qualitative studies by Blyth *et al.* (1984) in sections of the Mitta Mitta River before the construction of Dartmouth Dam, and in the Mitchell River by Ahern and Blyth (1978). Of the 34 most abundant species recorded in the upper LaTrobe catchment (Metzeling *et al.*, 1984), 17 were represented in the 34 most abundant taxa collected here. Of the 48 most common species collected at an undisturbed site on the Thomson River (Museum of Victoria, unpublished data), 26 were among the 48 most common taxa recorded here. The main areas of species overlap between these studies tend to be in the leptophlebiid Ephemeroptera, some of the Plecoptera, glossosomatid and leptocerid Trichoptera and many of the Chironomidae (Diptera) and Elmidae (Coleoptera).

Effects of Agricultural Disturbance

The clearing of land for agricultural purposes may have several effects on a stream which could influence the macroinvertebrate communities, although the problem has received little attention in Australia. These influences may include increases in soil erosion, solar radiation and nutrient run-off from fertilizers, or a decrease in organic input through leaf-fall. In this specific case, housing and high intensity tourist activity may also have some effect on the river communities.

Species which characterise the main dichotomy of the TWINSPLAN analysis (Figure 4) may have been restricted in their distribution by one or more of these influences. Although the status of species that are indicative of clean water and undisturbed substrata in Victoria is presently unclear, previous work (e.g. Marchant *et al.*, 1985; Museum of Victoria, unpublished data) suggests that some of the taxa collected in this study may prove useful as sensitive indicators of relatively undisturbed upland sections of Victorian rivers. Those included in Figure 4 which appear to have the most potential as sensitive indicators are *Atalophlebioides* sp. 1 and *Helodidae* sp. 1. Both of these species were reduced in abundance at sites disturbed by construction of the Thomson Dam (Museum of Victoria, unpublished data). The low numbers of these taxa at sites 9, 10, 15, 16 and 17 (Table 1) suggests that some impact from human disturbance has occurred at those sites. This agrees well with the observation that these sites do seem to be the most heavily altered by human activity. Further work on the remaining taxa noted in Figure 4 would be required to establish their environmental requirements.

However, the high diversity, even at the disturbed sites, suggests that

the levels of aquatic disruption are not as serious as found in other, more disturbed rivers in Victoria, where the total species diversity is severely depressed and the faunal composition is totally different to that found at undisturbed sites. That many of the taxa seem to be evenly distributed over the study area, at both disturbed and undisturbed sites, implies that the above mentioned indicator species, which are reduced in abundance at the disturbed sites, are sensitive to fairly minor disturbances.

Conclusions

The macroinvertebrate communities at sites flowing through relatively undisturbed natural vegetation in rivers draining into Lake Eildon seem to be typical of the fauna of the upland-foothill transition zone in Victorian rivers. Diversity was high and the fauna was dominated by many species from the leptophlebiid Ephemeroptera, the Plecoptera, Trichoptera, elmids beetles, Chironomidae (Diptera) and Oligochaeta. Some of these taxa may prove to be useful as indicators of clean water quality and undisturbed substratum conditions.

Other sites in the study area appeared to be somewhat affected by the influences of human activity, including agricultural clearing, bankside housing and tourist use. Although similar numbers of taxa were collected at each site, there was a clear distinction between the sites on the lower reaches of the Goulburn, Jamieson and Howqua Rivers in both the DECORANA and TWINSpan results (Figures 2 and 4), although the affinities of sites 8 and 12 were somewhat obscure. These distinct sites (9, 10, 13, 15, 16 and 17) were located in areas that had the highest density of housing and agricultural clearing, and the species composition at most of these sites was characterised by reductions in the abundance of species that previous work in this department has suggested may be deleteriously affected by the influences of human disturbance (e.g. *Atalophlebioides* sp. 1, Helodidae sp. 1).

Acknowledgements

This project was jointly funded by the Rural Water Commission, the Soil Conservation Authority, Fisheries and Wildlife, and the Department of Minerals and Energy. Comments expressed in this paper do not necessarily concur with the opinions of the funding bodies.

Dr R. Marchant conducted the original sampling and sorting, and he and John Blyth provided helpful comments on the draft. Peter Lillywhite, Leon Barmuta, Bob Marley, Gary Morgan and several anonymous referees also contributed significantly to the production of this paper.

References

- Ahern, L.D. and Blyth, J.D. (1978). Mitchell River Environmental Survey: quantitative study of the invertebrate fauna. Mitchell River Project: Supplementary Report on Environmental Studies. State Rivers and Water Supply Commission, Melbourne.
- Blyth, J.D., Doeg, T.J. and St. Clair, R.M. (1984). Response of the macroinvertebrate fauna of the Mitta Mitta River, Victoria, to the

- construction and operation of Dartmouth Dam. I: Construction and initial filling period. *Occ. Pap. Mus. Vic.* 1: 83-100.
- Doeg, T.J.** (1984). Response of the macroinvertebrate fauna of the Mitta Mitta River, Victoria, to the construction and operation of Dartmouth Dam. II: Irrigation release. *Occ. Pap. Mus. Vic.* 1: 101-127.
- Furse, M.T., Moss, D., Wright, J.F. and Armitage, P.D.** (1984). The influence of seasonal and taxonomic factors on the ordination and classification of running water sites in Great Britain and on the prediction of their macroinvertebrate communities. *Freshw. Biol.* 14: 257-280.
- Gauch, H.G.** (1982). 'Multivariate Analysis in Community Ecology.' (Cambridge University Press, Cambridge).
- Hill, M.O.** (1979a). 'DECORANA — A FORTRAN Program for Detrended Correspondence Analysis and Reciprocal Averaging.' (Ecology and Systematics, Cornell University).
- Hill, M.O.** (1979b). 'TWINSPAN — A FORTRAN Program for Arranging Multivariate Data in an Ordered Two-way Table by Classification of the Individuals and Attributes.' (Ecology and Systematics, Cornell University).
- Hynes, H.B.N.** (undated). Annotated key to the stonefly nymphs (Plecoptera) of Victoria. Australian Society for Limnology, Special Publication No. 2.
- Land Conservation Council.** (1973). 'Melbourne Study Area Report.' (Land Conservation Council, Melbourne).
- Marchant, R., Mitchell, P. and Norris, R.** (1984). Distribution of benthic invertebrates along a disturbed section of the LaTrobe River, Victoria: an analysis based on numerical classification. *Aust. J. Mar. Freshw. Res.* 35: 355-374.
- Marchant, R., Metzeling, L., Graesser, A. and Suter, P.** (1985). The organisation of macroinvertebrate communities in the major tributaries of the LaTrobe River, Victoria, Australia. *Freshw. Biol.* 15: 315-331.
- Metzeling, L., Graesser, A., Suter, P. and Marchant, R.** (1984). The distribution of aquatic macroinvertebrates in the upper catchment of the LaTrobe River, Victoria. *Occ. Pap. Mus. Vic.* 1: 1-62.
- Pielou, E.C.** (1984). 'The Interpretation of Ecological Data.' (John Wiley and Sons, New York).
- Sokal, R.R. and Rohlf, F.J.** (1969). 'Biometry.' (W.H. Freeman and Co., San Francisco).
- State Rivers and Water Supply Commission** (1984). 'Victorian Surface Water Information to 1982: Volume 3.' (State Rivers and Water Supply Commission, Melbourne).
- Wright, J.F., Moss, D., Armitage, P.D. and Furse, M.T.** (1984). A preliminary classification of running water sites in Great Britain based on macroinvertebrate species and the prediction of community type using environmental data. *Freshw. Biol.* 14: 221-256.

